Ellis Llwyd Jones Hall
Library.

12.12.32.

THE CLIMATES OF THE CONTINENTS

THE CLIMATES OF THE CONTINENTS

By W. G. KENDREW, M.A.

Second Edition

OXFORD
AT THE CLARENDON PRESS

OXFORD UNIVERSITY PRESS
AMEN HOUSE, E.C. 4
LONDON EDINBURGH GLASGOW
LEIPZIG NEW YORK TORONTO
MELBOURNE CAPETOWN BOMBAY
CALCUTTA MADRAS SHANGHAI
HUMPHREY MILFORD
PUBLISHER TO THE
UNIVERSITY

Impression of 1930
First edition, 1922
Second edition, 1927

Printed in Great Britain

PREFACE

This book aims at filling a gap in the sources available for the study of the geography of the Earth. For some time there has been no lack of treatises on meteorology; excellent works exist also on the general principles of climatology, describing the features of the main types of climate; but there is no adequate description of the actual climates of the countries of the Earth, considered regionally, available in English. It is necessary to refer to foreign sources, most of them German, for more information than the short sketches contained in general works on geography. Only for a few regions are there detailed accounts in English.

A work of this kind must be essentially a compilation from such materials as statistics, more or less adequate, maps showing certain factors of climate, and regional descriptions; the result is largely dependent on the nature of the original sources. A glance at the following pages will show that no uniformity of treatment has been achieved or even attempted. The principle followed has been to present the main features of the climate of each region considered especially in relation to the greater units of the globe. It is clearly impossible to give any detailed local descriptions in a book of this scope. But it is hoped that the general account may constitute a framework into which detailed local descriptions may be intelligently fitted, a convenient skeleton to carry the details necessary for the special purposes of the meteorologist, the botanist, the zoologist, and the geographer.

As it seemed desirable to make each chapter as far as possible complete in itself, repetition has been in some places inevitable.

A general knowledge of meteorology is assumed. In view of the many existing books on that subject it was thought unnecessary to explain points of meteorology, except from the regional standpoint.

The fullest acknowledgement is tendered to the authors of the works, and to the persons responsible for the other sources,[1] which are the foundation of this book. Without such sources a compilation of this kind would have been impossible ; and it will be obvious to the reader that in many chapters little has been attempted beyond setting them out in a form suitable to the plan of the book. On pp. ix and x is a list of some of the more important of them. The less important works, including those in which climate is only an incidental topic, and the numerous papers in the publications of the Meteorological Societies and Organizations at home and abroad, are for the most part not mentioned owing to lack of space and to the difficulty of making a list which should be complete. Special obligations must be expressed to the veteran climatologist, Dr. J. von Hann, author of the most comprehensive work on climate, the *Handbuch der Klimatologie*. That work, together with the innumerable articles which Dr. Hann has contributed to the various meteorological journals, especially the *Meteorologische Zeitschrift*, have long constituted him the leading authority on the subject. His writings have been not only an inspiration, but the most valuable mine of information for later workers. No book on climate can fail to show the constant influence of his assiduous labours in collecting and interpreting statistics. He kindly gave a cordial sanction for the use made here of his works in the week before his death.

---

[1] Especially to the following, who have kindly given permission for the use of maps on which many of the figures have been based: John Bartholomew & Son, Ltd., the Edinburgh Geographical Institute (figs. 7 and 8, based on A. Knox, *The Climate of the Continent of Africa* ; 28 and 107, based on A. Buchan, *Atlas of Meteorology*) ; the Secretary of State for India in Council (figs. 38, 40, 42, 43, 45, 46, 49, 51, 53, 55, based on the *Climatological Atlas of India*) ; the Royal Geographical Society (figs. 33 to 37, 78, 79, based on A. J. Herbertson, *Distribution of Rainfall over the Lands*) ; Messrs. Ginn & Company (fig. 95, based on W. M. Davis, *Elementary Meteorology*) ; H. M. Stationery Office (figs. 6, 30, 31, 76, 100, 124, 125, based on A. Buchan, *Challenger Reports* ; fig. 75, based on *Weekly Weather Report*) ; and to Messrs. Macmillan & Co., Ltd., for permission to print extracts (on pp. 101, 126, 127) from H. F. Blanford's *Climates and Weather of India, Ceylon, and Burma.*

The *Atlas of Meteorology* (Bartholomew and Herbertson) has been constantly referred to; without such maps as are collected in that atlas it would be almost impossible to make intelligent use of climate statistics.

The writer wishes to offer his very sincere thanks to several old pupils and other friends, and to the Staff of the Clarendon Press, for advice and help given at all stages in the preparation of the book. He is particularly indebted to Miss C. E. Clegg; and to Mr. H. O. Beckit, Reader in Geography in the University of Oxford, who generously put his time and experience at his disposal.

OXFORD, 1921.

LIST OF WORKS

Hann, J. *Handbuch der Klimatologie.* Stuttgart, 1908.

Woeikof, A. *Die Klimate der Erde.* Jena, 1887.

Hettner, A. *Die Klimate der Erde. Geogr. Zeit.* XVII.

Buchan, A. 'Reports on Atmospheric Circulation,' *Challenger Reports,* Edinburgh, 1889.

Herbertson, A. J. *The Distribution of Rainfall over the Lands.*

Oxford Survey of the British Empire. Oxford, 1914. (Articles on climate by various authors.)

Lyons, H. G. *Physiography of the Nile Basin.* Cairo, 1906.

Craig, J. J. *The Rains of the Nile Basin.* Cairo, 1913.

Schirmer, H. *Le Sahara.* Paris, 1893.

Knox, A. *The Climate of the Continent of Africa.* Cambridge, 1911.

Imperial Gazetteer of India ('Meteorology,' Chap. III, vol. i). Oxford, 1909.

Blanford, H. F. *The Climates and Weather of India, Ceylon, and Burma.* London, 1889.

Eliot, J. *Handbook of Cyclonic Storms in the Bay of Bengal.*

Woeikof, A. 'Le Climat de la Sibérie orientale.' *Annales de Géographie.* Paris, 1897–8.

Woeikof, A. Article on the Climate of Russia in Kirchhoff, *Länderkunde von Europa,* III. Teil. Vienna, 1907.

Maurer, Billwiller and Hess. *Das Klima der Schweiz.* Frauenfeld, 1909.

Philippson, A. *Das Mittelmeergebiet.* Leipzig, 1904.

Fischer, T. 'Studien über das Klima der Mittelmeerländer.' *Petermann's Mittheilungen,* Ergänzungsheft No. 58. Gotha, 1879.

Angot, A. 'Études sur le climat de la France.' *Annales du Bureau Central météorologique,* 1897, 1900, 1902, 1903.

Schott, G. *Geographie des Atlantischen Ozeans.* Hamburg, 1912.

Summary of the Climatological data for the United States, by various authors. U.S. Dept. of Agriculture, Weather Bureau, 1909.

Bulletins (various) on the Climate of the United States, U.S. Dept. of Agriculture, Weather Bureau.

The Geography and Geology of Alaska. Section on Climate by Cleveland Abbe. Washington, 1906.

Voss, E. L. 'Die Niederschlagsverhältnisse von Südamerika.' *Petermann's Mittheilungen*, Ergänzungsheft No. 157. Gotha, 1907.

Mossman, R. C. 'The Climate of Chile.' *Jour. of the Scot. Met. Soc.*, 1911.

Davis, W. G. *Climate of the Argentine Republic.* Buenos Aires, 1902.

Carvalho, C. de. *Météorologie du Brésil.* London, 1917.

Hunt, Quayle, and Taylor. *The Climate and Weather of Australia.* Melbourne, 1913.

Griffith Taylor. *Australian Meteorology.* Oxford, 1920.

ADDENDUM

Brooks, C. E. P. 'Articles on Climates.' *Quar. Jour. R. Meteorological Soc.*

Simpson, G. C. 'The South-West Monsoon.' *Quar. Jour. R. Meteorological Soc.* July 1921.

Hellmann, G. *Untersuchungen über die jährliche Periode der Niederschläge in Europa.* Preussische Akad. der Wissensch. 1924.

Weickmann, L. *Zum Klima der Türkei.* Munich.

Ward, R. de C. *The Climates of the United States.* New York, 1925.

Jefferson, M. 'The Rainfall of Chile.' *American Geogr. Soc. Research Series*, No. 7.

Morize, H. *Contribuição ao Estudo do Clima do Brasil.* Rio de Janeiro, 1922.

Simpson, G. C. *British Antarctic Expedition: Meteorology.*

ATLASES

Bartholomew. *Atlas of Meteorology.*

Hann, J. (Berghaus). *Atlas der Meteorologie.* Gotha, 1887.

Eliot, J. *Climatological Atlas of India.* Bartholomew, 1906.

Rykatcheff, M. *Russian Climatological Atlas.* St. Petersburg, 1900.

Atlas de Finlande. 1910.

Deutsche Seewarte. *Atlantischer Ozean.* Hamburg, 1902.

" " *Stiller Ozean.* Hamburg, 1896.

" " *Indischer Ozean.* Hamburg, 1891.

CONTENTS

THE CLIMATES OF THE CONTINENTS

PART I. INTRODUCTORY

CHAP. PAGE
1. On Climate Statistics 1
2. Pressure and Wind Systems 6

PART II. AFRICA

3. General Features 11
4. Mediterranean Africa 19
5. The Sahara 24
6. The Sudan west of Lake Chad ; the Guinea Lands . . 28
7. The Sudan east of Lake Chad ; Egypt . . . 39
8. Abyssinia and Somaliland 42
9. Kamerun 45
10. The Congo Basin 46
11. Kenya Colony (British East Africa) and Uganda . . 50
12. Tanganyika Territory (German East Africa) . . 57
13. Angola 60
14. South-West Africa 61
15. Nyasaland and Northern Rhodesia 63
16. Portuguese East Africa 65
17. Madagascar 66
18. British South Africa 68
Statistics 81

PART III. ASIA (with European Russia)

19. General Features 89
20. India, Ceylon, and Burma 95
21. China 132
22. Japan 139
23. South-east Asia and the East Indies 144
24. South-west Asia 148
25. The Heart of Asia 154
26. Tibet 162
27. The Russian Empire 167
Statistics 190

PART IV. EUROPE (excluding Russia)

CHAP. PAGE
28. General Features 197
29. North-west Europe 210
30. Central Europe 218
31. The Mediterranean Lands 233
Statistics 252

PART V. NORTH AMERICA (excluding Mexico)

32. General Features 262
33. Pressure and Winds 265
34. Temperature 269
35. Rainfall 286
Statistics 299

PART VI. SOUTH AND CENTRAL AMERICA, MEXICO, AND THE WEST INDIES

36. General Features 303
37. The west coast, south of the Equator 312
38. The Andes Plateau 319
39. South America, north of the Equator 322
40. Brazil, Uruguay, and Paraguay 325
41. The Argentine Republic 330
42. Mexico, Central America, and the West Indies . . 335
Statistics 340

PART VII. AUSTRALIA AND NEW ZEALAND

43. General Features 345
44. Australia: Temperature 348
45. Australia: Pressure and Winds 353
46. Australia: Rainfall 356
47. Australia: Tropical cyclones; hot winds and cold winds 363
48. New Zealand 365
Statistics 369

PART VIII. ANTARCTICA (p. 373)

Table of Equivalents, Temperature °F. and °C., inches and millimetres 386
Index 388

LIST OF ILLUSTRATIONS

PART I. INTRODUCTORY

FIG. PAGE
1. Belts of pressure and winds 7
2. Modification of planetary belts of pressure by a continent . . 9

PART II. AFRICA

3. Key map, showing the position of places mentioned in the text . 12
4. Mean isobars and prevailing winds, January and July . . 14, 15
5. Prevailing winds 16
6. Mean isotherms 18
7. Mean annual rainfall 20
8. Mean rainfall, January, April, July, and October . . . 21
9. Mean temperature at Géryville, Mogador, Algiers, and Alexandria . 22
10. Mean monthly rainfall at Géryville and Algiers 23
11. Rainfall of the Guinea lands 33
12. Mean monthly rainfall, Cape Coast Castle, Freetown, and Bismarckburg 34
13. Temperature and rainfall at Timbuktu 36
14. Temperature curves for the Nile valley 40
15. Rainfall in the Nile valley 41
16. Rainfall of the Congo Basin 48
17. The major climate regions of East Africa 52
18. Mean temperature and rainfall at Nairobi 54
19. Madagascar. Prevailing winds 66
20. Typical tracks of tropical cyclones over the S. Indian Ocean . . 67
21. Mean temperature at Durban and Kimberley 71
22. Mean monthly rainfall at Cape Town, Durban, and Kimberley . 74
23. Mean rainfall for ten-day periods at Bulawayo 75
24. Rain wind-rose for Bulawayo 76
25. Proportions of rainfall in summer and winter, South Africa . . 77
26. Mean monthly rainfall at Port Elizabeth 78
27. Major climate regions of the Cape Province 78
28. Mean isotherms, January, South Africa 79

PART III. ASIA

29. Key map, showing the position of places mentioned in the text . 90
30. Mean isotherms 91
31. Mean isobars and prevailing winds, January and July . . 91
32. The duration of the monsoon rains 92
33. Mean annual rainfall 92
34. Mean rainfall in January 93
35. Mean rainfall in April 93
36. Mean rainfall in July 94

FIG. PAGE
37. Mean rainfall in October 94
38. India. Mean isobars and prevailing winds, January . . . 96
39. ,, Typical tracks of cold weather cyclones 99
40. ,, Mean rainfall of the cold weather season 100
41. Mean monthly rainfall at Srinagar and Lahore 100
42. India. Mean isotherms, January 102
43. ,, Mean isotherms, May 104
44. Mean temperature at Calicut, Calcutta, and Mooltan . . . 105
45. Mean isobars and prevailing winds, April 106
46. Mean rainfall of the hot-weather season 107
47. Conditions before and after the setting-in of the S.W. monsoon . 109
48. The main currents of the S.W. monsoon 110
49. India. Mean rainfall during the season of general rains . . . 111
50. The winds round the Thar Desert 114
51. India. Mean isotherms, July 117
52. Mean temperature and rainfall at Bombay 118
53. India. Mean rainfall during the season of the retreating monsoon . 119
54. Mean rainfall at Peshawar, Madras, and Goalpara . . . 120
55. India. Mean isotherms, October 121
56. ,, Typical storm tracks 122
57. ,, The major climate regions 125
58. Mean monthly rainfall at Hong Kong, Shanghai, and Peking . . 136
59. Mean rainfall at Tokio and Kanazawa 141
60. The prevailing winds of the East Indies region 144
61. Some typhoon tracks of the China Sea 147
62. Mean temperature, Wadi Halfa and Kashgar 158
63. The main climate regions of Tibet 163
64. The prevailing winds round the Caspian Sea 169
65. Mean isotherms in the neighbourhood of Lake Bajkal in December 173
66. Mean isotherms in the neighbourhood of Lake Baikal in July . 175
67. Mean range of temperature, Russian Empire 177
68. Mean temperature at Yakutsk, Tobolsk, Moscow, and Riga . . 178
69. Mean number of days rivers are ice-bound each year, Russian Empire 180
70. The ice in the Gulf of Bothnia on March 1, 1905 181
71. Period of heaviest precipitation, Russian Empire . . . 183
72. Mean rainfall at Tashhent, Yalta, and Barnaul 186
73. The major climate regions of the Russian Empire 187

PART IV. EUROPE

74. Key-map, showing the position of places named in the text . . 198–9
75. Irregularities of pressure over the North Atlantic, 7 a.m., August 26, 1912 201

FIG. PAGE
76. Isotherms, January, April, July, October 205
77. Lines of equal anomaly of temperature in January . . . 206
78. Mean annual rainfall 207
79. Mean rainfall, January, April, July, October 209
80. The major climate regions of Europe 211
81. Mean isotherms for January over Scandinavia 212
82. Mean monthly rainfall at Valencia and Cambridge . . . 215
83. Regions with more rain in winter than in summer half year . . 217
84. Seasonal rainfall at Brest, Paris, and Munich 220
85. Seasonal rainfall at Brest and Buda-Pest 220
86. Temperature during a Föhn wind, January 13, 1895, 1 p.m. . . 229
87. Mean relative humidity at Lucerne and Rigi 230
88. Isotherms, 40° January and 70° July 234
89. The distribution of the Olive tree 235
90. Mean isotherms, January, north Italy 237
Cyclone tracts of the Mediterranean region . . *to face* 238
91. Mean rainfall at Athens and Marseilles 242
92. Mean rainfall at Albacete and Turin 243
93. Mean temperature at Lisbon and Athens 245
94. The major climate regions of the Iberian peninsula . . . 247
95. Pressure and winds and temperature over the Iberian peninsula . 248
96. The major climate regions of Italy 249
97. Major climate regions of the Balkan peninsula 251

PART V. NORTH AMERICA

98. Key map, showing the position of places named in the text . . 263
99. Mean isobars and prevailing winds, January and July . . . 266
100. Mean isotherms, January, April, July, and October . . . 270
101. Absolute minimum temperature 275
102. Pressure and temperature conditions during a ‘ cold wave ’ . . 276
103. Mean isotherms in July, California 279
104. Mean temperature at San Francisco and Mount Tamalpais . . 281
105. Frequency of tornadoes 285
106. Mean annual rainfall 287
107. Mean monthly rainfall 289
108. Rainfall régimes 291
109. Monthly rainfall at Olympia 293
110. ,, ,, Port Simpson 293
111. ,, ,, San Francisco and San Diego . . . 293
112. ,, ,, Boisé and Salt Lake City 293
113. ,, ,, Gila Bend and Flagstaff 293
114. ,, ,, Omaha, Bismarck, and Winnipeg . . . 295
115. ,, ,, Fort Chipewyan 295
116. ,, ,, Galveston and Raleigh 295
117. ,, ,, St. Louis 295
118. ,, ,, Pittsburg 295

FIG. PAGE
119. Monthly rainfall at Toronto, Montreal, New York . . . 297
120. " " Parry Sound, St. John's, and Halifax . . 297
121. " " Vladivostok 297
122. " " Vicksburg and Knoxville 297

PART VI. SOUTH AMERICA

123. Key map, showing position of places mentioned in the text . . 304
124. Mean isotherms, January, April, July, October 305
125. Mean isobars and prevailing winds, January and July . . . 307
126. Seasonal distribution of rainfall in South America . . . 309
127. Mean monthly rainfall 310
128. Mean annual rainfall 311
129. Section across the west of South America in lat. 20° S. . . . 313
130. Mean temperature at Quito and La Paz 320
131. Mean monthly rainfall at Cuyaba, Manaos and Pernambuco . . 326
132. The main climate divisions of the Argentine 331
133. Mean monthly rainfall at San Juan, Santiago, and Buenos Aires . 332
134. " " " Santiago (Chile) and Mendoza . . 333
135. Cyclone tracks of West Indies region 338

PART VII. AUSTRALIA AND NEW ZEALAND

136. Key map, showing the position of places named in the text . . 346
137. Mean isotherms, January, April, July, October 349
138. Number of consecutive days on which air temperature has exceeded 90° 350
139. Monthly temperature at Alice Springs, Adelaide, and Port Darwin . 351
140. A 'col' and a 'trough' 354
141. Mean isobars and prevailing winds, January and July . . . 355
142. Mean annual rainfall 357
143. Mean rainfall at Darwin 358
144. " " Alice Springs 359
145. " " Adelaide 359
146. " " Dubbo 359
147. " " Brisbane 360
148. Mean rainfall, January, April, July, October 361
149. Typical paths of tropical cyclones 363

PART VIII. ANTARCTICA

150. Key map, showing the position of places named in the text . 373
151. Mean wind directions 378
152. Wind velocity and temperature during a blizzard . . . 379
153. Mean monthly temperature 383

PART I

INTRODUCTORY

CHAPTER I

ON CLIMATE STATISTICS

THE most important of the elements which combine to form climate are temperature and rainfall. These have been more carefully and frequently observed than the other factors such as sunshine, cloudiness, and humidity, which are subsidiary though by no means unimportant. Hence it seems well to make some general remarks here concerning temperature and rainfall, to which such constant reference will be made in the following pages.

Temperature. The air temperature at any place is constantly changing, and it is clearly impossible to give a complete statement of such a varying element. In climatic descriptions it is usual to state the average temperature, and also to indicate, if possible, in some way how far the temperature from day to day may be expected to vary from that average. 'Average temperature' is an abstraction, and if it is to be of real significance the extremes of the individual figures from which it is derived must not be very far apart. Hence for most parts of the world the mean temperature for the year is the least satisfactory statement of that element; Peking and the Scilly Islands have almost the same mean annual temperature, while the monthly means range from 79° to 23° at Peking, from 61° to 43° at the Scilly Islands. In the neighbourhood of the Equator, it is true, the annual mean is a useful figure since the temperature varies little from month to month. But in general it is necessary to supplement it with the mean monthly temperatures. Means for a shorter period than a month would be still more valuable, but they entail overburdensome statistics.

The mean temperature for any day is in most cases taken to be the mean of the highest and lowest temperatures of that day, recorded in the shade under certain recognized conditions to ensure uniformity of observation. The mean for a month is the mean of the daily means, and the mean for a year the mean of the twelve monthly means. By subtracting the mean temperatures of the warmest and coldest months we obtain the ‘ annual range ’, a most important element. At Peking the mean annual range is seen from the figures given above to be 56°, at the Scilly Islands, 18° ; in the neighbourhood of the Panama Canal it is only 1°. True means are obtained arithmetically from the figures for the day, month, or year for a long period, if possible 35 years. The ‘ mean diurnal range ’ for any period is the average difference between the highest and lowest temperatures for each day in that period, usually a month being taken, for a series of years, and it also is a valuable figure. For example, London has a mean diurnal range of 20° in July, the average daily maximum for that month being 74°, the average daily minimum 54° ; the Scilly Islands enjoy a more equable climate, having a mean diurnal range in July of only 9°. The limits within which the mean diurnal range varies in different parts of the earth are not so far apart as those for the annual range. Both the diurnal and the annual range depend largely on the position of the station, on or near the sea or inland, and on the humidity of the atmosphere, the highest range being found in the heart of an arid desert far removed from sea-influence. The annual range is controlled very much by latitude also, since the amount of the seasonal change of insolation depends on the latitude.

It must be noted that the diurnal range is considerably greater than the annual range in many parts of the world, especially near the Equator. Thus at Bolobo (Congo) the mean diurnal range is 16°, the mean annual range only 2°. It may at first seem surprising that the range of temperature from day to night should exceed that for the year, which includes 365 days and nights, but in reality there is no inconsistency involved, since the annual range is calculated from the mean monthly temperatures, in which the daily extremes are combined so that they neutralize each other.

All the world over the average temperature becomes less with increase of altitude, and the rate of decrease is approximately the same everywhere, about 1° for 300 ft. of elevation. Fort William is 15° warmer on the average than Ben Nevis, some

4,400 ft. higher. Hence for some purposes of comparison it is possible and convenient to 'correct' the actual temperature to its 'sea-level value' by adding 1° for every 300 ft. of elevation. In drawing isotherms these corrected temperatures are used, and where isotherms are referred to in this book they must be understood to be the usual sea-level isotherms. But with this exception all temperatures mentioned are actual observed temperatures not corrected to sea-level, unless the contrary is stated.

A glance at any isotherm map shows that the temperature varies greatly along any parallel of latitude. The mean temperature for the parallel may be obtained by taking an average of the temperatures at a large number of points spaced evenly along it. The difference between this mean and the temperature at any place on the parallel is called the 'anomaly of temperature' for that place, a positive anomaly if the place is warmer than the mean, a negative anomaly if it is colder. 'Isanomalous lines' for any month or for the year are lines drawn through places with the same anomaly. The greatest temperature anomaly on the earth is over the north-east of the Atlantic Ocean in January, where a large area has a positive anomaly of more than 20°; the British Isles belong to this favoured region (Fig. 77, p. 206). Anomalies are calculated from temperatures which have been reduced to sea-level. They assist us in analysing the complex influences to which the temperature of any place is due. In calculating them we really eliminate the effect of latitude; the effect of altitude has already been eliminated, and thus the map of isanomalous lines presents us with a simpler picture, showing chiefly the influence of land and sea, ocean currents and prevailing winds.

Among temperature statistics it is useful to indicate the highest and lowest temperatures that normally occur in each month, or, to use the technical terms, the mean daily maximum and mean daily minimum for each month. These figures can only occasionally be given in this book owing to limitation of space. The extreme temperatures that have ever been recorded, called technically the 'absolute maximum' and 'absolute minimum', are also interesting and useful, provided that the records have been kept for a sufficiently long time. Short records are even less valuable in this connexion than for establishing average values. The longer the observations are continued the higher the absolute maximum and the lower the absolute minimum may be expected to prove themselves. Records of less than 35 years are not trustworthy, but in 35 years samples of the greatest heat and the greatest cold to which a place is liable will probably have been experienced. Indeed in the case of most climatic statistics, especially for periods of less than a year, we cannot rely on the accuracy of mean values which are obtained from less than 35 years' observations. Unfortunately, in lieu of better, many figures are included in the following pages which depend on much shorter records. The length of the record is not stated, but the statistics given are believed to be the best available.

Rainfall. A mere statement of the average total amount of rainfall for the whole year at any place is not sufficient. It must be supplemented by some indication of the seasonal distribution. The mean rainfall for each month ought to be given. The significance of the seasonal distribution is well known to the botanist and the geographer. Thus it is a matter of fundamental importance to the plant world whether the rain falls during the warmest or the coldest season. Hence constant reference will be made to this aspect of rainfall, since it is not only a feature of interest to the meteorologist, but an important factor in the life of plants and therefore of animals and men.

The seasonal distribution or 'régime' is independent of the total rainfall amount. Two stations may each have twice as much rain in summer as in winter, or in other words, they may have the same régime, but the total annual rainfall at one may be many times greater than at the other. Or again, two stations may have the same mean annual rainfall, but the régimes may be different, one station having most of its rain in summer, the other, perhaps, having equal amounts in all seasons. In order to compare more conveniently the distribution of the rainfall over the year at stations with different annual totals, we may express the rainfall for each month or for each season as a percentage of the total for the year. The main rainfall régimes are the following:

(i) equatorial; two seasons of heaviest rain in the course of the year, at or about the time of the overhead sun; intervening months much less rainy but there is no pronounced dry season. It occurs only within a few degrees of latitude on each side of the Equator, e. g. at Yaundé, Kamerun.

(ii) tropical; found between the zone of (i) and the tropics of Cancer and Capricorn; most rain during the hottest months when the sun is highest; 'winter' a pronounced dry season. We may subdivide into:

(*a*) with two maxima of monthly rainfall; found between the equatorial zone and the neighbourhood of lat. 15° north and south; it approximates to the equatorial régime, but the two maxima, agreeing with the times of the overhead sun, are closer together, and there is a long dry season during 'winter', e. g. Mongalla (R. Nile).

(*b*) with a single maximum; found on the poleward side of (*a*); the two maxima of (*a*) here coalesce, and the dry season is longer, e. g. Khartoum.

(iii) monsoon; a pronounced maximum in summer, and a long dry season, much like ii (*b*); found both inside and outside the tropics especially on the east coasts of continents, e. g. Peking.

(iv) Mediterranean; most rain in the winter six months, with either a single maximum in November or December or with two maxima in autumn and spring respectively; summer is almost, or quite, rainless, e. g. Athens.

(v) continental interiors of temperate latitudes have most rain in summer (late spring and early summer in the steppes); winters much less rainy but not rainless; the periodicity is not so marked as in the monsoon and Mediterranean types.

(vi) west coasts of continents in temperate latitudes have abundant rain in all seasons, with the maximum in autumn or winter. Mountains cause a local modification of the rainfall régime as well as an increase in the amount of rain in their neighbourhood in many places.

The nature of the rainfall is an important element. The rain may be of the thunderstorm type, falling usually in heavy showers during the hottest part of the day; or cyclonic, falling irrespective of the time of day, less heavy but often lasting longer than thunderstorm rain; most of the rain of the British Isles is cyclonic. Or again the precipitation may be mainly drizzle, or even dew.

Snow, too, is included in rainfall statistics unless specially excepted, a foot of snow being considered equivalent to an inch of rain. It is useful to know also the average number of days on which there is appreciable precipitation, that is to say 0·01 inches or 0·1 mm. according to the usage of most observers.

It is important to remember that the months are of unequal length, and therefore their rainfall totals are not directly comparable as an exact expression of the monthly distribution.

CHAPTER II

PRESSURE AND WIND SYSTEMS

It is not our intention to give an introductory account of the distribution of the climatic elements over the globe as a whole. Such an account may be found elsewhere, and in this book we attempt rather to describe the climates of individual countries. But it may be useful to sketch here the main features of the distribution of atmospheric pressure and the prevailing winds. Generally speaking pressure is not an element of climate. Its fluctuations, even in regions where they are greatest, are not perceptible to us except with the help of delicate instruments. It is only where the pressure is reduced to two-thirds or a half of the normal at sea level that we can consider pressure an element of climate, as for instance on high mountains where a direct physiological effect is produced, the rarefaction of the air causing mountain sickness. But indirectly pressure, as controlling the wind systems, may be truly said to be a fundamental element in climate everywhere, for climate probably depends more on the prevailing winds than on any other single factor.

Fig. 1 shows the distribution of pressure which would probably exist, for reasons which may be found in works on meteorology, on a planet in other respects like the earth, but having a homogeneous surface, all land or all water. This ‘ planetary ’ arrangement of pressure is one of belts parallel with the Equator. The resulting great ‘ planetary ’ wind systems are also arranged in belts. The usual names given to these belts of pressure and winds are shown in the figure.

But the surface of the earth is far from homogeneous. The arrangement of land and water causes irregularities in the distribution of temperature, and these in turn produce pressure irregularities, all pressure differences being due ultimately to differential heating. We must allow, moreover, in dealing with the actual earth for the temperature differences between continents and oceans in the various seasons. In the planetary arrangement the only important effect of the seasonal changes would be to cause a swing of the whole system of belts of temperature, pressure, and winds. But the conditions on the earth are much more complicated.

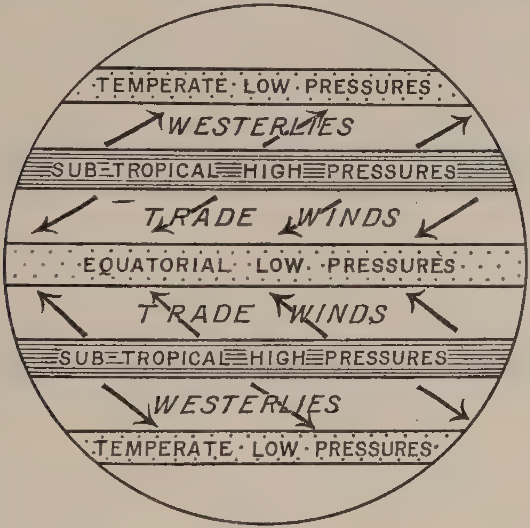

TEMPERATE LOW PRESSURES
WESTERLIES
SUB-TROPICAL HIGH PRESSURES
TRADE WINDS
EQUATORIAL LOW PRESSURES
TRADE WINDS
SUB-TROPICAL HIGH PRESSURES
WESTERLIES
TEMPERATE LOW PRESSURES

FIG. 1.

Fig. 2, based on Hettner (*Die Klimate der Erde*), shows in diagrammatic form the arrangement actually found. The land masses are represented by a triangle with its base in the northern and its apex in the southern hemisphere, in order to suggest the main land masses of the earth. In the first diagram it is summer in the northern hemisphere and the pressure belts have swung north. The land masses in the summer hemisphere have heated rapidly and low pressures tend to spread and deepen over them. The low-pressure systems so formed are extensions of the equatorial low pressures, and they break the continuity of the subtropical belt of high pressure. The air which is thrown off from the heated continents finds a place partly in the winter hemisphere and partly over the relatively cool oceans of the summer hemisphere. The subtropical high-pressure belt of the summer hemisphere is represented by detached anticyclones over the oceans, where pressure is higher in summer than in winter. The low-pressure belt of temperate latitudes coalesces with the continental low pressures. In the southern hemisphere the land is cool but its area is small, and hence there is no very great disturbance of the planetary belts.

The planetary winds are of course profoundly modified, in parts almost beyond recognition, by these modifications in the distribution of pressure. The south-east trades are drawn across the Equator into the northern hemisphere, and coming under the influence of right-handed rotational deflection, appear as south-west winds, generally light in force, which we shall refer to in later chapters as ‘deflected trades’. But on the east coast of our continent, the winds that start as south-east trades are drawn far into the northern hemisphere as the summer monsoon, a most important current. It will be noticed that this monsoon is a reversal of the trade winds which formed a belt round the whole of our homogeneous globe. In reality the trades blow only in the eastern and central parts of the oceans in their appropriate latitudes in summer. They are the outflowing winds on the east and south sides of the subtropical anticyclones over the oceans, and blow from the north on the east side of the centre of high pressure, from the north-east on the south-east, and from the east on the south of this centre. Over the ocean north of the subtropical anticyclones the wind is westerly in summer as in winter, but it is lighter in force in summer. It is drawn in somewhat towards the continent and becomes in places north-west. Along the north coast of the continent the wind is north-east.

In January (second diagram of Fig. 2) the land in the northern hemisphere is very much colder than the sea, and the subtropical high pressures are enormously intensified over it. Indeed the most prominent features of the isobar map of the earth for January are the great anticyclones over Asia and North America. The oceans have relatively low pressures, but the subtropical high-pressure belt is traceable over them, though it is much less pronounced than in July, and the temperate low pressures are deepened, forming the so-called 'permanent cyclones' over the northern parts of the oceans, vast depressions representing the temperate low-pressure belt which is interrupted in winter by the continents, where high pressures extend far north. The continental anticyclone affects the winds profoundly. The winter monsoon blows out from it on the east coast and continues across the Equator; it blows from the north-west at first, becomes north, then north-east, and finally, after crossing the Equator, north-west; generically it is a modified and strengthened trade wind; thus the trade winds extend in a belt right round the globe in winter. The stormy westerlies sweep with great violence over the northern oceans; their direction is variable from day to day, under the control of the numerous cyclones which travel from west to east, but the resultant air movement is from the west and south-west on the equatorial side of the most frequented cyclone tracks. On the north coast of the continent the wind is west. Thus we may say that the planetary belt of westerly winds is still continuous round the globe in winter but is thrust poleward by the continental anticyclones so that in temperate latitudes the wind is south-west on the west side of the continent, west on the north, and north-west on the east, the interior of the continent being a region of comparatively calm air.

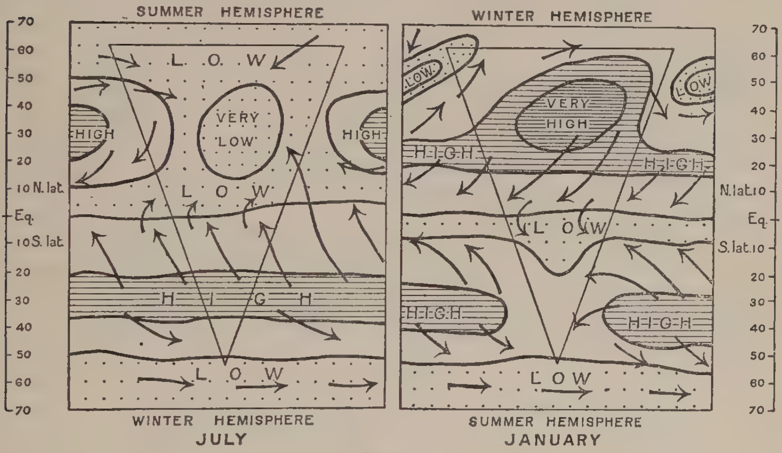

SUMMER HEMISPHERE
WINTER HEMISPHERE
70
60
50
40
30
20
10 N. lat.
Eq.
10 S. lat.
20
30
40
50
60
70
LOW
VERY LOW
HIGH
HIGH
LOW
HIGH
LOW
WINTER HEMISPHERE
JULY
LOW
LOW
VERY HIGH
HIGH
HIGH
LOW
HIGH
HIGH
LOW
N. lat. 10
Eq.
S. lat. 10
SUMMER HEMISPHERE
JANUARY

FIG. 2.

The land mass in the southern hemisphere is hotter than the sea in January and the equatorial belt of low pressures spreads south ; not so much, however, as was the case in July in the northern hemisphere, since the land area is smaller. The north-east trade is drawn south over the Equator and becomes a north-west wind. The south-east trade is drawn in by the heated land and becomes an east wind, in places north-east, so that the planetary trade wind belt is interrupted just as in the northern hemisphere in July, though to a less extent.

PART II

AFRICA

CHAPTER III

GENERAL FEATURES

Africa, alone of the continents, extends to almost equal distances north and south of the Equator. The southern part projects far into the ocean, remote from other land masses, but in the north-east Africa adjoins Asia, and the climate of a large portion of Africa is controlled to a great extent from Asia. Yet in spite of this external control we can trace very clearly the same series of climates northward from the equatorial belt of heat and moisture to the shores of the Mediterranean Sea, and southward to the Cape of Good Hope. The Sudan has its counterpart in Rhodesia, the Sahara in the arid tracts of the Kalahari and South-west Africa, the Mediterranean coast in the district round Cape Town.

The continent lacks extensive mountain ranges such as are so effective elsewhere as climate barriers. Gradual transitions take the place of the sudden changes of climate to which the Andes, for example, give rise. Africa, however, has vast areas of plateau, especially in the south and east where much of the surface is more than 3,000 feet above the sea, and here the climate is dry and invigorating, and well suited for European settlement even in latitudes which are usually very unhealthy near sea-level.

Oceanic conditions. The west coast of North Africa is washed by the Canaries current. This is a cool current, partly owing to the direction of its flow from north to south to feed the north equatorial current, partly owing to the upwelling of cold water along the coast under the influence of prevailing off-shore winds; thus the surface of the sea at Mogador has been observed to be at 60° F., while 20 miles out at sea the surface temperature was 70°. The effects of the Canaries current can be distinctly traced from the Strait of Gibraltar as far south as 12° N. lat. in February and 17° N. lat. in August in the low temperatures, frequent fogs

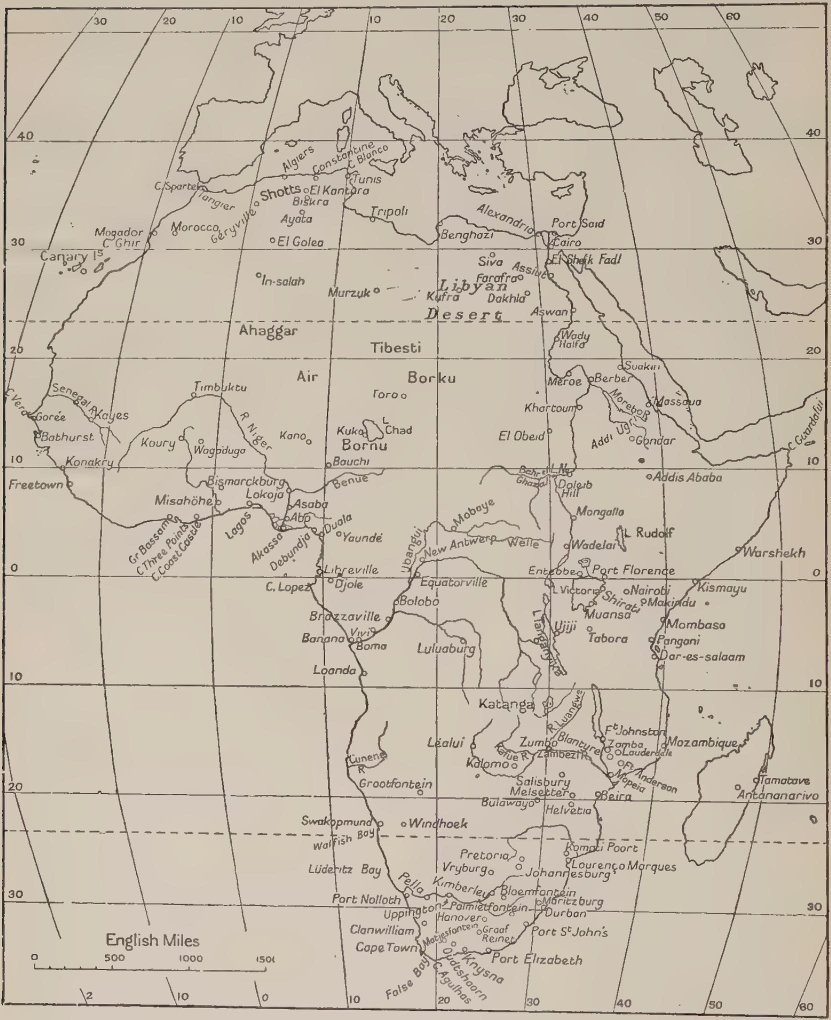
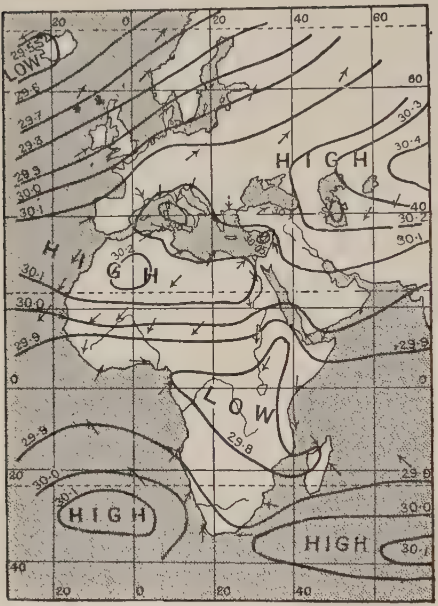

30
20
10
10
20
30
40
50
60
40
40
Algiers
Constantine
C. Blanco
Tunis
C. Spartel
Tangier
Shotts
El Kantara
Biskra
Ayata
Tripoli
Alexandria
Port Said
Mogador
C. Ghir
Morocco
Géryville
El Golea
Benghazi
Cairo
30
30
Canary Is.
Siva
Assiut
El Sheik Fadl
In-salah
Murzuk
Libyan
Farafra
Kufra
Dakhla
Desert
Aswan
Ahaggar
Tibesti
Wady Halfa
20
20
Suakin
Air
Borku
Meroe
Berber
Timbuktu
Toro
Senegal R.
C. Verde
Kayes
Gorée
Khartoum
Massaua
Moreb R.
Chad
Kuka
Bathurst
Koury
Wagadugu
R. Niger
Kano
Bornu
El Obeid
Addi Ugri
Gondar
C. Guardafui
10
Konakry
Bauchi
10
Freetown
Bismarckburg
Lokoja
Benue
Bahr el Ghazal
Bahr el Jebel
Addis Ababa
Doleib Hill
Misahöhe
Asaba
Mobaye
Mongalla
Abo
Duala
L. Rudolf
Gr. Bassam
C. Three Points
C. Coast Castle
Lagos
Akassa
Debundja
Yaundé
New Antwerp
Welle
Wadelai
Ubangui
Warshekh
0
0
Libreville
Entebbe
Port Florence
C. Lopez
Djole
Equatorville
L. Victoria
Nairobi
Kismayu
Bolobo
Shirati
Makindu
Brazzaville
Muansa
Vivi
L. Tanganyika
Ujiji
Mombasa
Banana
Boma
Luluaburg
Tabora
Pangani
Dar-es-salaam
Loanda
10
10
Katanga
R. Luangwa
Ft Johnston
Lealui
Zumbo
Blantyre
Zomba
Mozambique
Blue R.
Zambezi R.
Lauderdale
Cunene R.
Kalomo
Ft Anderson
Mopeia
Grootfontein
Salisbury
Tamatave
20
Melsetter
Beira
Antananarivo
Bulawayo
Helvetia
Swakopmund
Windhoek
Walfish Bay
Komati Poort
Pretoria
Vryburg
Lüderitz Bay
Johannesburg
Lourenço Marques
Pella
Kimberley
Bloemfontein
30
Port Nolloth
Maritzburg
30
Upington
Palmietfontein
Hanover
Durban
English Miles
Clanwilliam
Matjesfontein
Graaf Reinet
Port St John's
0
500
1000
1500
Cape Town
Port Elizabeth
Oudtshoorn
Knysna
False Bay
C. Agulhas
20
10
0
10
20
30
40
50
60

FIG. 3. Africa. Key Map, showing the position of places mentioned in the text. For East Africa see Fig. 17.

and scant rainfall of the coast. The conditions on the coast and in the interior are notably different, especially in summer. In August the mean temperature of the sea does not exceed 65°, while the arid sands inland may reach 160° about mid-day under the blazing overhead sun. The Benguela current south of the Equator corresponds to the Canaries current in the north, and it is still more important in its climatic effects, which are in evidence from the Cape of Good Hope almost to the Equator. The coolest water is found off the south of South-west Africa, where the mean sea-surface temperature is below 55° in August, 57° in February. A cool foggy seaboard, much of it an almost rainless desert, is, in part at least, the result of these oceanic conditions. Between the Canaries and the Benguela currents the warm waters of the Guinea current, with a temperature of over 80°, bring excessive heat and moisture to the coast between Cape Verde and Cape Lopez in summer, Freetown and Cape Lopez in winter.

The ocean currents on the east coast of Africa present a striking contrast. The equatorial currents of the Indian Ocean bear along enormous masses of heated water, which, meeting the African coast almost at right angles, spread out to north and south. The southern branch continues as far as Cape Agulhas, and is warmest and most powerful in February when the prevailing winds are north-east; the mean sea-surface temperature is over 80° at the Equator, and 77° off Natal in that month. In August the prevailing winds are southerly and consequently more of the heated water is driven northward; the sea temperature off Natal falls to 68°, while it exceeds 76° everywhere north of Mozambique except in a narrow strip along Somaliland between Cape Warshekh and Cape Guardafui, where the mean temperature is only 60°. The reason for the presence of this cool water appears to be that the prevailing winds in summer are south-west, and they cause an upwelling of the lower layers of the ocean along the coast.

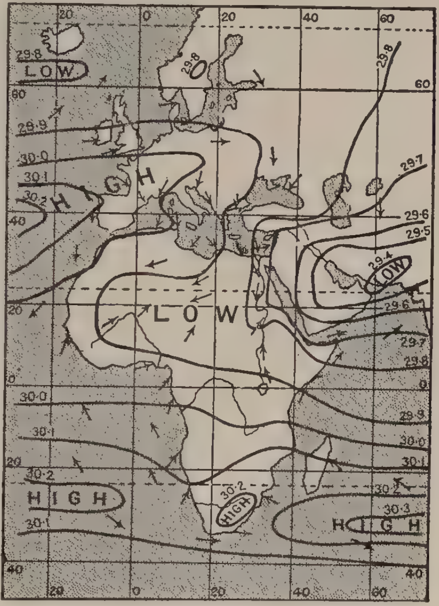
The Red Sea is very hot at all seasons, but the climatic importance of that fact is greatest in winter. On summer days the water, hot though it is, even exerts a cooling influence on the still hotter sun-baked desert coasts. The Red Sea is too narrow to have more than a very limited local influence. The Mediterranean on the other hand is very important in its effect on the meteorology and climate of all the north of Africa. In winter the warm moist air over the sea engenders low atmospheric pressure, and as a result the weather of the surrounding coasts is mild and rainy. In summer the sea does not become so hot as the land and the high pressures normal to the subtropical latitudes in which the Mediterranean is situated spread over it; the great extent of the Sahara is largely due to this fact. The annual range of temperature of the sea surface is considerable both in the Mediterranean, where it is 25°, and in the Red Sea, where it is 15°. In autumn the Mediterranean retains much of its summer heat, but by spring it has cooled considerably, and hence autumn is notably warmer than spring in the Mediterranean lands.



January

Fig. 4a. Mean Isobars and prevailing winds.

Pressure. January (Fig. 4 a). In the winter of the northern hemisphere the great difference in temperature between land and sea north of the tropic of Cancer causes the theoretical belt of high pressure in subtropical latitudes to be profoundly modified, since vast high-pressure systems are developed on its northern side over the cold land masses of Asia and America. These continental anticyclones are the most prominent features of the pressure distribution. Over the North Atlantic and Europe we find what may be considered as a 'bridge' of moderately high pressures connecting the continental anticyclones. The continuation of this bridge north of Africa is of the highest importance in the meteorology of the continent. The high pressures over the North Atlantic are centred at about 30° N. lat., those over Asia at about 45° N. Between them lies the Mediterranean region, an area of warm and moist air in winter, with a tendency to low pressures. The high-pressure bridge therefore takes up its position not over but to the north and to the south of the Mediterranean, that is to say over Europe where it is most marked, and over the north of Africa; and between the two bands of high pressure is the Mediterranean ‘ lake ’ of low pressure, the path of numerous cyclones. These cyclones are closely connected with those of the westerlies of North-west Europe; some enter the Mediterranean as fully developed systems, others form or deepen over the warm sea. It is more accurate to regard the Mediterranean in winter as an independent meteorological area than as merely an extension of the region of the oceanic westerlies.



July

Fig. 4b. Mean Isobars and prevailing winds.

As over the Mediterranean, so in the neighbourhood of the Red Sea there is a break in the high-pressure belt, probably for the same reason.

Along the north coast of Africa all the way from Morocco to Egypt, the prevailing winds in winter are westerly, controlled by the low pressures over the Mediterranean (Fig. 5). The high-pressure belt over the north of the Sahara is a region of calms and variable winds, and south of it we enter the arid region where the north-east trades hold undisputed sway. Sweeping across the Sahara and the Sudan, they blow almost to the shores of the Gulf of Guinea in the west, beyond the Equator in the centre of the continent, and as far as about 15° S. lat. in the east. Their goal is the low-pressure system, the modified doldrums, which now covers Africa south of the Equator and extends westward in a long trough over the Upper Guinea coast about 5° N. lat. The northerly position of this trough is explained by the fact that even in January the southern Sahara and the Guinea lands are warmer than the South Atlantic Ocean. On the Guinea coast, therefore, south-west winds, 'deflected trades', are frequent even in winter, bringing with them the hot steamy weather of the 'white man's grave'. Travelling west along this coast we reach the trades on approaching Sierra Leone, and north of this point white men find life bearable for at least part of the year.

Over South Africa low pressures replace the normal subtropical high pressures in January owing to the heating of the land by the overhead sun. The south hemisphere 'belt' of high pressure appears in the form of well-marked anticyclones over the South Atlantic and South Indian Oceans, about 30°–40° S. lat., connected by a 'bridge' over the extreme south of Cape Province, which enjoys fine weather and sunny skies in the southern summer. The south-east trades, strengthened by a monsoonal indraught, blow as a steady current from the anticyclone which lies over the Indian Ocean on to the east coast of Africa as far north as Mozambique. Having crossed a wide expanse of warm sea, they give copious rain where they are forced to ascend over the lofty eastern edge of the African plateau. Onshore winds blow on the west coast of Africa also, but they are merely coastal sea breezes and, having come from a cold sea, they bring no rain. Some little distance off this coast we find the south-east trades, which start here on their long journey to the doldrums, which, over the Atlantic Ocean, are north of the Equator.

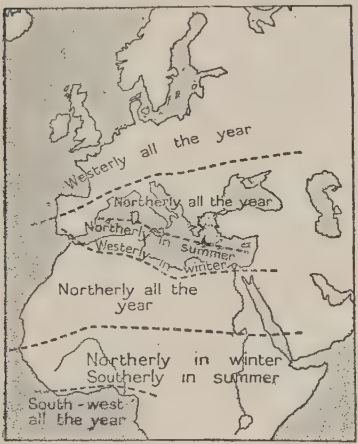


FIG. 5. Prevailing Winds.

July. (Fig. 4 b) During the northern summer the subtropical high pressures of the northern hemisphere are found in very well-marked anticyclones over the Oceans. The continents are relatively hot, the air over them expands, and low-pressure systems result. Africa is influenced especially by two of these systems. The first, the North Atlantic Anticyclone, lies mainly west of the Straits of Gibraltar, but has an eastward extension over much of western Europe and the Mediterranean Sea. Africa north of the Equator, especially the Sahara, is strongly heated by the blazing sun, and hence the high pressures of the Mediterranean are sharply limited by the north coast of the continent. The second, the low-pressure system over the south of Asia, centres in Baluchistan and Sind. North Africa forms with Asia a vast hot land area, and a great westward extension of the Asiatic low pressures develops over the Sahara. If the latest isobar maps give a true picture of the conditions, a notable change in the pressure gradient occurs at the Nile valley; eastward of the Nile the isobars are close, circling round the low-pressure centre, while over the Sahara there is an extensive region of slight gradient. This continental low-pressure system represents the doldrums drawn far north and extended by the interaction of land and sea. The trough of lowest pressure crosses Africa from Suakin on the Red Sea, through Berber to the mouth of the Senegal River, and forms a most important divide between the dry north-east and north winds which blow out of the Atlantic and Mediterranean high pressures on the north, and the rainy south and south-west winds which are drawn in from the south. All Africa north of this line is arid in summer except for a little rain in the mountains, and occasional violent cloud-bursts in the plains; it is largely to the influence of the Mediterranean Sea in maintaining high pressures immediately north of Africa, that the great extent of the Sahara is due. But for the high pressures which extend east over the Mediterranean Sea, the trade winds would have less force, and the monsoon, which produces the heavy rainfall and luxuriant vegetation of the Guinea lands, would make its way much farther into the continent and fertilize the southern part of the Sahara.

The low-pressure system swings from its extreme southern position in January to its extreme northern position in July, lagging in general about one month behind the overhead sun. It migrates through about 13° of lat. in the west of the continent, and about 40° in the east.

The southern hemisphere is under winter conditions in July.

The land is cooler than the surrounding oceans and a high-pressure system is developed over South Africa, forming part of the subtropical belt of high pressure, and causing fine dry weather. At this season too the oceanic high pressures have moved somewhat north of their January position, leaving Cape Town and the southern tip of Cape Province exposed to the stormy westerlies which give a considerable winter rainfall. Natal has calms and weak onshore winds, but between the tropic of Capricorn and Cape Guardafui the wind blows parallel to the shore, towards the Asiatic low pressures. The west coast of South Africa is under the influence of the south-east trades, which are now at their greatest strength, but sea breezes mask them on the immediate littoral.

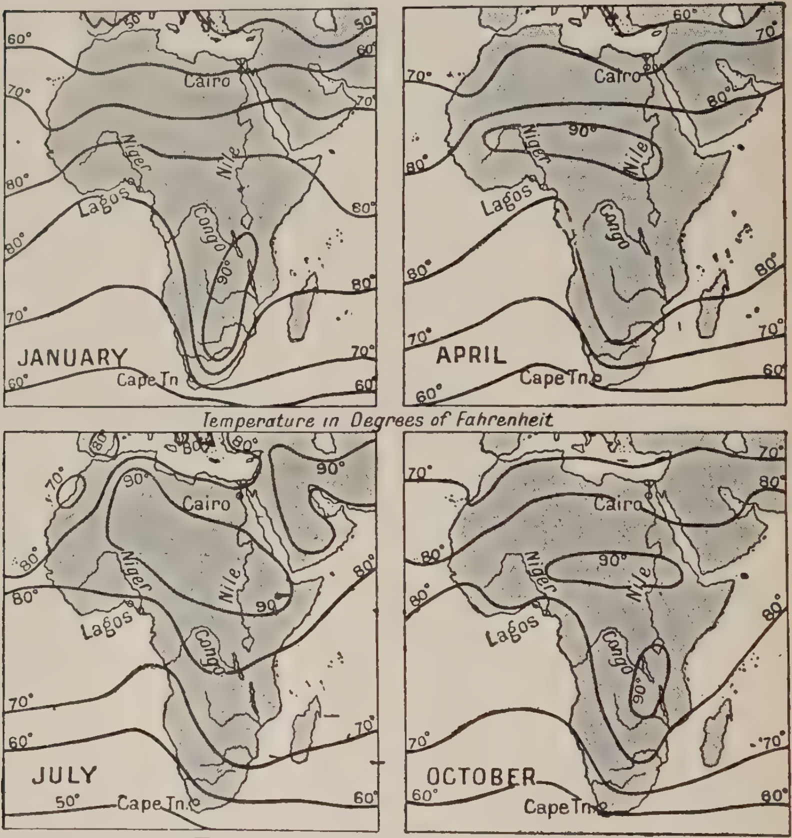

Temperature in Degrees of Fahrenheit
JANUARY
60°
50°
60°
Cairo
70°
Niger
Nile
80°
Lagos
Congo
90°
Cape Tn
APRIL
Cairo
70°
80°
90°
Niger
Nile
Lagos
Congo
60°
Cape Tn
JULY
80°
90°
70°
Cairo
Niger
Nile
Lagos
Congo
60°
50°
Cape Tn.
OCTOBER
70°
Cairo
80°
90°
Niger
Nile
Lagos
Congo
60°
Cape Tn

FIG. 6. Mean Temperature. (Buchan.)

Temperature. Africa may be truly described as the hottest of the continents, whether we consider the mean annual, the summer, or the winter temperature (Fig. 6). Especially is this so in the summer of the northern hemisphere, when the vast areas of the Sahara have the highest temperature of the Earth. Africa is the only continent in which the 50° isotherm never appears. The greater part of the continent has more than nine months with a mean temperature above 70°, and only the Atlas lands, Abyssinia, the Drakensberg Mountains, and the cool desert littoral of South-west Africa have less than seven months.

A distinction which will be constantly referred to, especially in dealing with South Africa, is that between the low coastal plain and the interior plateau. In general, the coasts within the tropics are rainy, enervating, and unhealthy owing to the monotonous moist heat; the plateau is less rainy and much more healthy since, though exceedingly high temperatures may occur by day, the air is dry, and moreover the cool fresh nights afford a welcome relief for European residents; the seasonal change of temperature also is much greater on the plateau.

Rainfall. The mean rainfall for the year is shown in Fig. 7, for January, April, July, and October in Fig. 8.

CHAPTER IV

MEDITERRANEAN AFRICA

THIS region comprises the northern parts of Morocco, Algeria, and Tunis where the rainfall exceeds 8 inches a year. Lands of very varied physiography are included. We must distinguish: 1. the coastal strip with a pure Mediterranean climate (p. 233); 2. the plateau of the Shotts, at an altitude of some 3,000–4,000 feet, with a steppe climate and vegetation; 3. the ranges of the Atlas which bound the plateau on the north and the south, generally exceeding 5,000 feet, and in Morocco attaining 10,000 feet; snow lies most of the year in the higher parts on the seaward side; 4. the Sahara south of the Saharan Atlas, but Saharan conditions prevail in parts of the plateau of the Shotts also. Divisions are also necessary from west to east: (1) the Atlantic coast of Morocco, (2) the Mediterranean from the Straits of Gibraltar to Tunis.

The Atlantic coast of Morocco is washed by the cool Canaries current which keeps the summer temperature low for the latitude (Fig. 9, Mogador); the coldest water is off Cape Ghir, the surface temperature showing the anomaly of decreasing southward from Cape Spartel; the mean air temperature in July is below 70° along much of this coast. The north-east trades blow strong in summer, but in winter westerly and south-westerly winds are frequent, since the cyclones of the westerlies often dominate the weather. Cool summers, small range of temperature, scanty rainfall but high humidity of the air, with heavy dews and frequent fogs, are results of the cold current. Between the coast and the Atlas Mountains the summers are hotter, the winters colder, and the rainfall less. The Atlas Mountains have rain in summer as

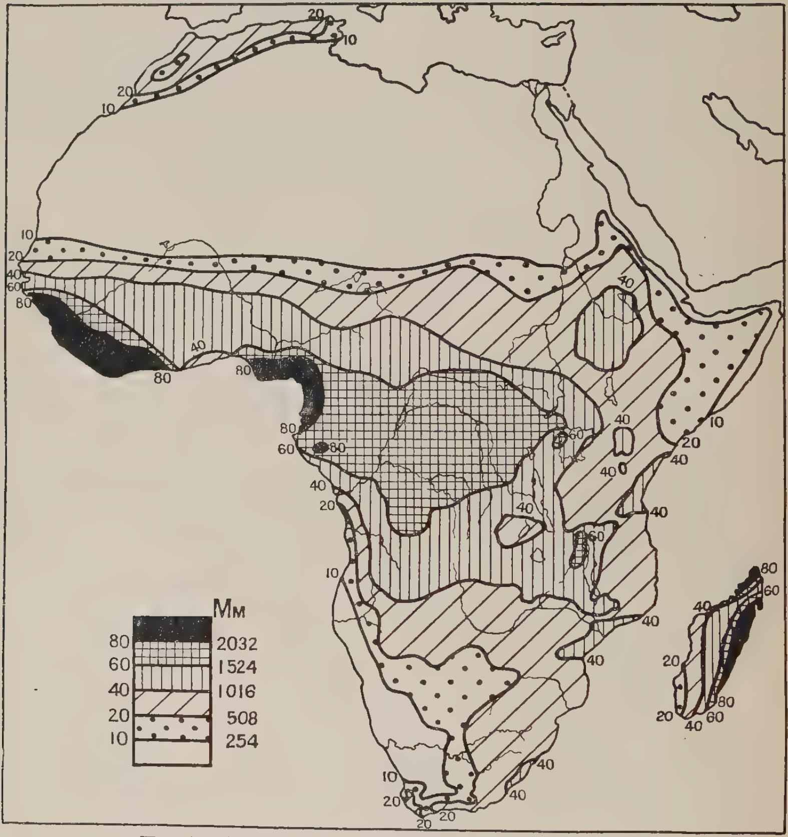


Fig. 7. Mean annual Rainfall in inches. (Knox.)

well as in winter, but elsewhere there is drought during the summer months; in the south of Morocco there is hardly a drop of rain from April to September. The land is sometimes swept, especially in spring, by the sirocco from the south-east, bringing hot and extremely dry air from the Sahara, with clouds of dust which is sometimes carried as far as the Canary Islands.

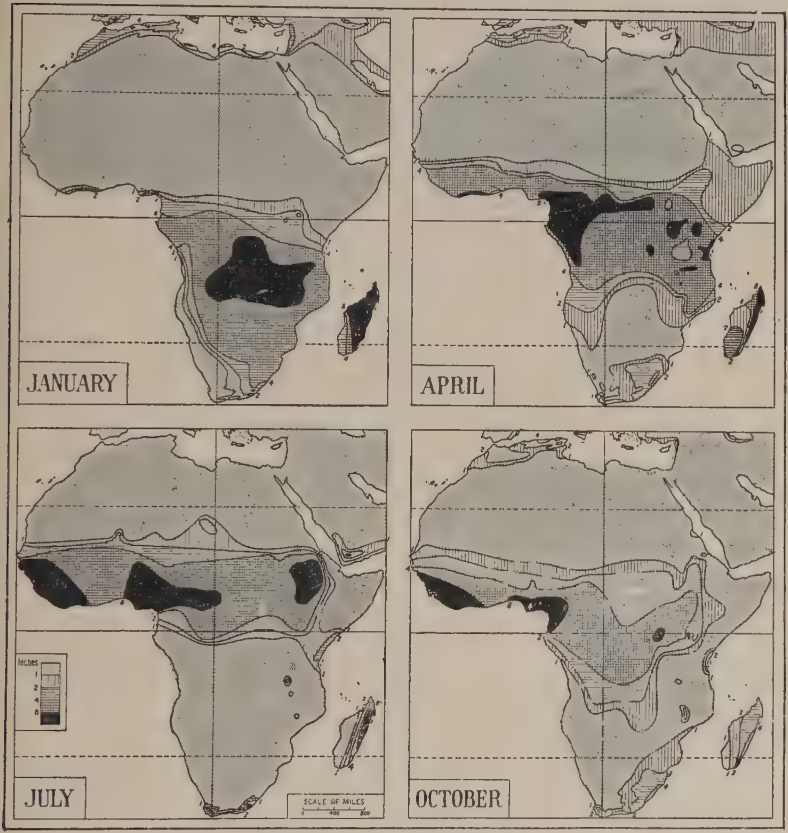


FIG. 8. Mean Rainfall.

Eastward from the Straits of Gibraltar the summers become much warmer, the sky being almost cloudless and the sunshine powerful. On the coastal plain the mean temperature in August, the hottest month, is about 75°; the prevailing north winds blowing from the sea prevent excessive heat. In winter the weather is controlled by depressions passing along the Mediterranean, which give south-west winds, with much cloud, moist air, and abundant rain; 80 per cent. of the rain falls in the winter half-year. The mean January temperature is 55°; frost is very rare. The sheltered valleys of the Tell have the best type of Mediterranean climate for agriculture, and are famous for orange and olive groves. The annual precipitation exceeds 20 inches everywhere, being least in the west in the lee of Spain, and probably exceeding 60 inches in Khroumirie on the north slopes of the mountains, where there is much snow in winter; here there are extensive forests of cork-oak, and above them cedars. The ranges of the Djurjura often rise snow-clad behind Algiers in winter.

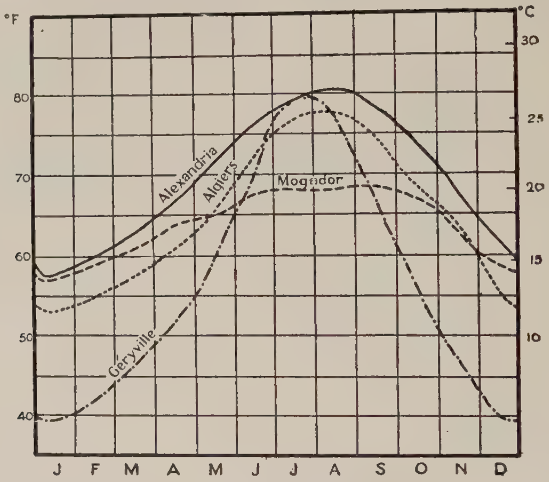


FIG. 9. Mean Temperature. Note the cool summer at Mogador, due to the Canaries Current; the hot summer but cold winter at Géryville (4,280 feet) as compared with Algiers on the coast.

The steppe climate of the plateau of the Shotts is the result of the altitude, and the distance from the sea whose influence is shut off by the Atlas ranges; a similar system forms a bounding wall towards the Sahara on the south. In winter it is often bitterly cold, when strong dry north winds sweep across the open plains at a temperature well below freezing-point, and there are sometimes severe snowstorms. On summer days on the other hand it is as hot as at sea-level, often hotter (Fig. 9), for the clear air gives free passage to the rays of the unclouded sun; the land is parched and the mirage mocks the traveller. Cool nights follow the hot days, the daily range of temperature being high. The mean annual precipitation is about 12 inches, with a strong maximum in spring due partly to the cyclonic activity of that season, partly to local convection; the low temperature in winter, and the steady northerly winds in summer, do not favour heavy precipitation, but there are some thunderstorms in summer and a certain amount of rain and snow in winter (Fig. 10). The region has the scanty rainfall and the extreme temperatures characteristic of steppe countries; alfa grass is the typical vegetation. The drier parts are very poor steppe.

The Saharan Atlas has a heavier precipitation than the plateau owing to the greater altitude, and there are even forests in places as in the massif of the Aures. The rain is the source of much of the underground water which supplies the oases of the neighbouring Sahara, and the possibility of using it for direct irrigation of parts of the desert is under consideration. The ranges form a sharp climatic divide. Looking north in spring we see the green steppes of the plateau, but at our feet on the south the sands of the Sahara stretch away to the horizon. Biskra has the Mediterranean winter rainfall maximum, but the scantiness of the rainfall, 8 inches, and the high range of temperature from day to night, and from winter to summer, show that it must be classed with the Sahara and not with the Mediterranean.

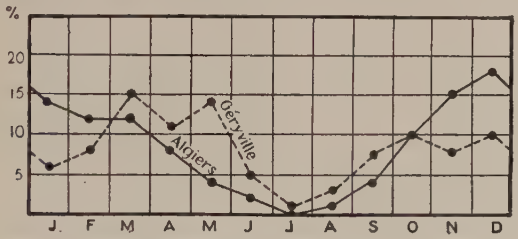


FIG. 10. Mean monthly Rainfall at Géryville and Algiers, expressed as percentages of the yearly total.

The remainder of the Mediterranean sea-board, North Libya and North Egypt, differ from Algeria and Tunis in having a more southerly position, and very high summer temperatures, in the absence of a mountain system to bound the Sahara behind them, and in their much smaller rainfall—Tripoli 16 inches, Benghazi 11 inches, Port Said 3 inches. The rain falls in winter but reaches only a narrow coastal strip ; thus Alexandria has 8 inches, Cairo only 1 inch. The prevailing summer winds are north-west, those of winter west and south as in the rest of this region. The sea tempers the heat for a short distance inland (compare the curves of temperature for Alexandria and Cairo, Fig. 14), but otherwise desert conditions reach the coast in many parts. Autumn is considerably warmer than spring, as everywhere on the Mediterranean.

Further information concerning this district will be found in pages 233 *et seq.*, where the climate and meteorology of the Mediterranean region as a whole is more fully considered.

CHAPTER V

THE SAHARA

The meteorology of the Sahara depends essentially on the fact that the barometric gradient over the region is from north to south throughout the year, causing perennial winds from a northerly point, generally north-east. In summer Saharan conditions extend northwards to cover the Mediterranean Sea, in winter southward almost to the Gulf of Guinea. The true Sahara covers some 13° of latitude. The prevailing winds are shown in Fig. 5.

During the winter months the north-east wind blows with great regularity over the centre and south of the Sahara. On the northern edge the direction of the wind shows itself more variable, and calms are frequent, this being the seat of the high-pressure ridge which separates the Sahara from the Mediterranean region. Wind observations taken at Murzuk by Rohlfs (1865–6) and by Nachtigal (1869–70) illustrate the conditions:

Percentage Wind Frequency at Murzuk

	N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm.*
Dec.–Feb. 1865–6 .	9	3	5	1	2	5	14	11	50
,, 1869–70 .	9	12	13	11	10	8	7	14	16

Records kept by the Rohlfs mission on its journey from the Nile to Farafra, Dakhla, and Siwa, give the following percentages :

	N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm.*
Dec.–Feb. 1873–4 .	13	2	3	3	1	4	16	20	37
Siwa, 1911–20 . .	2	1	8	1	1	3	30	0	54

The mean frequencies, Dec.–Feb., for Cairo and El Golea are:

	N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm.*
Cairo . . .	10	2	1	3	28	6	3	3	44
El Golea . .	32	14	7	6	5	9	8	18	

At Asyut 80 per cent. of the winter winds blow from north-west, north, or north-east.

In summer winds from a northerly or easterly point show a decided predominance in the northern as well as the central parts of the Sahara:

Percentage Wind Frequency in Summer (June–August)

	N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm.*
Cairo . . .	43	8	3	0	1	1	12	15	17
Aswan . . .	83	3	0	0	1	2	1	5	5
Kufra (Rohlfs, July–Sept.) . . .	37	17	7	6	3	1	3	26	

But in the south, south-west winds begin to make their appearance and the southern limit of the desert is found about 18° N. lat. where these rain-bringing winds become predominant in summer.

The northerly winds of the Sahara have the usual trade wind characteristics but are more than usually dry in this great land mass. Clouds are rare, sunshine is very abundant throughout the year, and the sun's rays beating down from the deep blue sky scorch the naked land. The summer temperatures are among the highest known on the earth. During the midday hours it is a veritable furnace. But the clear dry air also favours rapid loss of heat from the bare ground after sunset, and the cool nights are delightfully refreshing.

'Suddenly, almost without a period of twilight, the sun rises into the clear sky. In this dry atmosphere its rays are already scorching in the early morning, and under the influence of the reflection from stone and sand the layer of air next the ground is warmed rapidly. There is no active evaporation to moderate the rising temperature. After 9 o'clock the heat is great and goes on increasing till 3 or 4 in the afternoon, when the quivering mirage is sometimes seen, produced by the vibration of the air, warmed as in an oven. The heat becomes slowly less towards evening. The sun, just before it sets, suffuses the sky, which is still cloudless, with a glow of colour. In the transparent night the rocks and sand lose their heat almost as rapidly as they acquired it, and the calmness of the atmosphere, which is so still that a flame burns without a tremor, also favours the cooling of the air. We shiver with cold and it is no uncommon thing in winter to find water on the surface of the ground frozen in the morning' (Schirmer, *Le Sahara*).

The Sahara, then, is a region of very great diurnal range of temperature. The mean daily range °F. at Dakhla Oasis is:

Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
30	33	34	36	36	33	31	31	29	29	29	29	32

In Borku, in May 1871, the mean daily maximum temperature was 112°, the mean daily minimum 67°, mean daily range 45°. Far higher figures than the mean of course occur. On May 15, 1871, at Toro, South Borku, the temperature at sunrise was 59°, at 2 p.m. 116°, range 57°. On Christmas day 1879, Rohlfs and Stecker observed a minimum of 31° and a maximum of 99°, giving a range of 68° for the day.

At night the temperature may fall below freezing-point; 23° has been recorded in the Libyan desert and also in the Algerian Sahara, and In-salah has on the average nine nights with frost in the year. The day temperatures in summer are the highest known on the earth for a large area. The highest reading ever recorded under standard conditions is 136·4° on September 13, 1922, at Azizia, 25 miles south of Tripoli, and here 110° is attained in each month from May to September every year. The rocky soil is sometimes baked to a temperature of 160°. Schirmer truly remarks 'the desert is a country with extreme temperatures, where in spite of latitude it is by turns colder than on the Mediterranean and warmer than on the Equator'. The annual range of temperature also is very large for the latitude. Thus Aswan has a mean temperature of 61° in January and 95° in July, range 34°.

To sum up the main reasons for the dryness of the air in the Sahara, the north-east trades which sweep the desert originate as currents of air settling downwards from the upper atmosphere in the subtropical high pressures. In descending, the air is warmed by compression as it reaches denser strata, and consequently, since it is not receiving any moisture, its relative humidity decreases. Thus in their origin the trades are dry winds, and as they blow towards the south they become warmer and warmer and hence the relative humidity is still further decreased. In lands which have a plant covering much moisture is transpired into the air by the leaves. This source is lacking in the Sahara for there is no vegetation. The climate is too dry to support plant-life, and owing to the lack of vegetation the air remains dry. At In-salah the mean relative humidity is 56 per cent. in winter, 36 per cent. in spring, 25 per cent. in summer, 39 per cent. in autumn.

There is very little rain or even cloud, the mean annual rainfall being less than 5 inches everywhere, and practically nil in the Libyan desert and Egypt. Cairo has 1·3 inches and in the Nile Valley south of that town even the smallest shower is rare. In the northern Sahara the little rain that does fall comes in the winter half year, most in spring and autumn, and is mainly caused by the Mediterranean depressions of that period. In the south such rain as there is falls in summer, being an extension of the monsoon rain of the Sudan, and as in the Sudan it is generally thunderstorm rain, sometimes very heavy while it lasts. Much of the Sahara receives no rain at all for years at a time. Black clouds sometimes pass over, but the trails of rain that can be seen descending from them are evaporated by the thirsty desert air before they can reach the ground. Thus it is evident that there is often no lack of moisture in the air, though the air may be so dry 'physiologically' that vegetation is absolutely precluded, and the finger-nails split. If the air is sufficiently cooled by ascent up mountains, or by cyclonic or convectional influences, there may be violent downpours of rain—as much as 2 inches in a single storm in regions which are quite rainless for years. The wadis rush along brim-full, and much damage may be done, but the underground water-supplies on which life depends are renewed.

The mountains in the Sahara are much more favoured than the plains. The southern groups of Air and Tibesti get a considerable rainfall every summer, often in thunderstorms of great violence which cause sudden floods in the neighbouring wadis. The unwary, both animals and men, who happen to be in their path, even far away from the storm area, may easily be swept away. The Ahaggar, farther north, is fortunate in getting a share both of the summer rains from the south and the winter rains from the north, and there are many running streams in its deep valleys. Some of the summits are snow-capped in winter.

Travel in the Sahara is often rendered unpleasant, and even entirely stopped by clouds of dust swept along by the strong winds which blow by day. Sometimes a real dust storm, known as a Simoon, is experienced, and the air is filled and darkened by the whirling dust-clouds. Strong southerly winds are specially hot and unpleasant, and they are distinguished everywhere by local names such as sirocco, chili, khamsin.

The Atlantic coast of the Sahara between Morocco and Senegal is washed by the cool Canaries current. The heat is much less than in the interior, especially in summer, the July mean being probably as much as 20° below that in the Libyan desert. Fogs are fairly frequent, as on all coasts washed by a cold current.

The Red Sea coast is distinguished by its great humidity and small range of temperature as compared with the rest of the Sahara. At Suakin the mean temperature in August is 95°, in January 72°; the daily range of temperature averages 24° in summer and only 12° in winter; the mean relative humidity is 49 per cent. in summer and 72 per cent. in winter. There is a mean annual rainfall of 9 inches, most of which falls during the winter months when the hot moist wind from the Red Sea meets the cooler hills inland. There is copious dew at night caused by the cooling of the warm moisture-laden air, the water deposited often equalling a heavy shower of rain.

The Saharan climate is not unhealthy. The summer days are hot indeed, but the air is very dry, cool, and invigorating at night. It presents a great contrast to the belt which we have to describe next, where the summer heat is uniformly great by night as well as by day, and is associated with high humidity, an exceedingly unhealthy combination for white settlers.

CHAPTER VI

THE SUDAN WEST OF LAKE CHAD; THE GUINEA LANDS

The antithesis of the Sahara is the region of the Congo and the Guinea coast where the abundant rainfall throughout the year and the constant moist heat produce the rank luxuriance of the almost impenetrable rain forest.

Separating these opposites there is a transition region, a belt of country stretching right across the greatest width of Africa, where there is rain in summer and a well-marked drought in winter, the length of the rainy and dry seasons varying according to the latitude. This is the Sudan, a region probably of great potential agricultural value, as yet only very partially developed and not entirely explored.

Pressure and winds. We have seen that in January the equatorial low-pressure system is south of the Equator over the continent, but in the Gulf of Guinea the trough is still north of the Equator, since the Guinea lands are warmer than the sea. The axis of the tongue of low pressure probably lies along or just south of the Guinea coast. The north-east trade winds which we have studied in the Sahara now sweep as far south as this line, and bring Saharan conditions almost to the coast (Fig. 5). The aridity, however, is somewhat tempered by the influence of the vegetation and the numerous rivers. South of the trough of low pressure south-west winds prevail, an extension of the south-east trades of the southern hemisphere which are deflected when they cross the Equator. On the coast itself the prevailing winds are south-west even in January, but they are then weaker than during the rest of the year and are much interrupted by calms. They are rain-bringing winds and are responsible for the moist heat which is so fatal to Europeans.

In March the sun is overhead at the Equator, but already the hottest zone is some 600 or 700 miles farther north, where the clear dry air permits a more rapid rise of temperature than can occur in the moist forested equatorial zone, and the equatorial low pressures have migrated far into the northern hemisphere. By July they have reached their highest latitude, the trades have their least extension southward, and the moist south-west winds from the Gulf of Guinea their greatest extension northward, bringing steamy heat and heavy rain far inland. The northern limit of the south-west winds in summer is the southern boundary of the Sahara. About the end of August the trough of low pressure begins its return journey towards the south. Hence it appears that the central parts of the region over which the low-pressure belt swings will experience a double pressure wave in the course of the year, the extreme north and the extreme south a single wave. The extreme north has dry north-east winds during the greater portion of the year, broken by a short spell of south-west winds in late summer, and the land is too arid for agriculture. The extreme south of the Guinea lands on the other hand is under the influence of the south-westerlies during almost the whole year. The climate is equatorial and the rain forest is as luxuriant as in the Congo. If we travel in July southward along the west coast of the Sahara we first meet south-west winds some distance north of the Senegal River. The mouth of the Senegal itself has south-west winds during the four summer months and north-east trades during the rest of the year. The duration of the south-west winds increases rapidly to the south. At Bathurst they blow for eight months and already in the south of Portuguese Guinea they are the prevailing winds throughout the year, and they continue so right along the Guinea coast. The south-west winds on the coast are in part merely sea breezes rather than a true monsoon ; the interior, beyond the reach of the sea breezes, appears to have longer spells of north-east wind in the winter months than the coast in the same latitude. In the middle of summer south-west breezes extend as far as about lat. 20° N. in the interior north of the Niger Bend. Four hundred miles out to sea, in the Cape Verde Islands, the north-east trades blow for nine almost rainless months ; August to October is the ‘ Tempo das Aguas ’, when south-west breezes bring sultry weather and rain.

Rainfall. In the Guinea lands the rainfall is by far the most important climatic factor. The year is divided into two seasons, the rainy and the dry. The heaviest rainfall occurs just to the south of the trough of low pressure, and so there tends to be a well-marked double rainfall maximum in the course of the summer, one as the low-pressure trough passes north, the other as it returns south. However, during the whole season of south-west winds there is considerable rainfall.

The rains are a time of intense life for the plant world which wakes from its annual sleep with their advent. For the European settler it is the most unhealthy part of the year. Fever is rife ; activity is almost impossible in the sweltering steamy heat. Unfortunately the district most visited by Europeans is the coast, precisely the region with the longest and heaviest rains, the pernicious effects of which are exaggerated by the foul odours that arise from the rotting vegetation and slimy ooze of the mangrove swamps. Especially Sierra Leone and the Niger delta have earned and fully deserve the reputation of possessing one of the most unhealthy climates in the world. Sierra Leone is known as the ‘white man’s grave’, but the interior of that colony, especially the higher parts (and much of the interior is mountainous) is far less unhealthy than the coast, where the wide expanses of mangrove swamp and the insanitary settlements provide ideal breeding-places for the mosquitoes which carry malaria. The application of scientific methods has already done much to diminish the unhealthiness, and we may expect still greater success in the future. But a country with a mean annual temperature of 80°, with only 4° difference between the temperatures of the warmest and the coolest months, and an annual rainfall of over 175 inches, can never become an ideal residence for Europeans.

The following description given by Borius of a day during the rainy season in Senegambia presents a vivid picture of the conditions that prevail over the whole of the Guinea lands.

‘The sun rises out of clouds which soon melt away under its rays. The air is fresh and pleasant, with a few puffs of wind from the south-west. Light white clouds spread fanwise from the horizon and cross the valley, slowly changing form. Soon after sunrise the shade temperature is 80°. The calm air gets hotter and hotter, and by 9 a.m. it is unpleasant to walk abroad, even with a sunshade. The wet ground reflects the bright sunshine, and this fact combines with the high temperature, the moisture-laden air, and the fever germs to make the sunshine at this season so dangerous.

‘About 10 a.m. in spite of an increase in temperature of perhaps 3°, the heat is still bearable and admits of a little activity. The south-west breeze is beginning but is irregular and seems to be on the point of dying away at any moment. At midday the thermometer is still rising, and by 1 p.m. it stands at 86°; the sun is hidden at times as a few cumulus clouds cross the sky from south to north; the surface wind oscillates between west and south-west, but is still very weak. By 4 p.m. the temperature is 88°; the sky is three-fourths clouded, and masses of cloud are piling up on the horizon; the wind often drops altogether. The heat now feels excessive, and though after 4 p.m. the thermometer hardly rises a degree yet the heat seems to be increasing considerably, and we are astonished that the thermometer does not show a greater rise. We perspire profusely on the slightest exertion.

'At 6 p.m. the sun disappears in thick clouds, which it colours a brilliant copper. It falls calm except for a few puffs from the south and south-west which bring no life and fail to reach the inside of the house. We have to go out on the roof to try to get a breath of cooler air. A little black cloud passes overhead from the south-west, and a few drops of rain fall from it but not enough to wet the ground. We go in again, but the heat indoors is overwhelming and we long desperately for a breeze. The water, which is kept in porous vessels, and which seemed cool in the morning, is now lukewarm. There is no need for a hygrometer to show that the air is saturated with moisture. The vapour pressure is 23 mm., and it is this high humidity that makes the heat so overpowering, although the actual temperature is not excessive.

'Nothing can be compared with the feeling of utter prostration that overcomes a European. Though he sits motionless in an arm-chair he perspires as after violent toil; his fatigue is not like what is felt after work, but rather a weakness in the limbs, and especially in the bones—an indescribable feeling of discomfort, which precludes all movement, all bodily or mental work, but yet forbids sleep. Clouds of mosquitoes swarm round him and he feels suffocated.

'At 10 p.m. it has fallen dead calm. The temperature still continues high and our discomfort becomes more depressing than ever. We can neither read nor work, to do so would require an effort of the will which we are incapable of making; our mental energy is sapped even more than our physical strength. Night drags on in this painful way unless a thunder-storm bursts, with heavy rain, in which case the temperature falls and we feel a salutary freshness in the air. We may form some idea of the painful conditions of life on the Senegal during the rains if we think of the discomfort sometimes felt in Europe just before a summer thunderstorm, and imagine that discomfort increased ten-fold.'

The rainfall diminishes from south to north; much of the south-west and south coast has over 100 inches per annum, Timbuktu only 9 inches, and at 17° N. lat. the average amount is probably inappreciable. It is impossible to lay down as a definite line on a map the exact limit of appreciable rainfall, since the conditions are very variable from year to year. There are no rain gauges, and conclusions have to be drawn from the vegetation. Districts which travellers have reported to be quite arid and apparently rainless have been found by later visitors to have an abundant plant covering. Thus the Sahara is bounded to the south by a debatable belt, which is far too arid for any cultivation, but in wet years may receive enough rainfall to produce good vegetation.

The 10-inch isohyet (Fig. 11) is an almost straight east—west line which runs from the mouth of the Senegal to Lake Chad; and not far south, and roughly parallel to it, are the isohyets of 20 and 30 inches. North of about 10° N. lat. there is only a single short rainfall season. Timbuktu has only two months, July and August, with more than 2 inches of rain. The rain is very variable in amount here from year to year, as in most arid countries. South of 10° N. lat. we find the double maximum clearly marked except on the south-west coast (Fig. 11). In the interior November to February is the dry season. Heavy rain begins in April, and the early summer maximum occurs in June. In July and August the rainfall is somewhat less, though still heavy, and in September the second maximum occurs, higher than that of June (Bismarckburg, Fig. 12). On the coast the rainfall régime is similar, but the early summer maximum is here far higher than the later one; almost two-thirds of the year's rain falls in April, May, and June. The August minimum is very pronounced, that month being practically rainless (Cape Coast Castle, Fig. 12). Sierra Leone and most of the Liberian coast have only one maximum; the rainfall increasing steadily till August and then diminishing

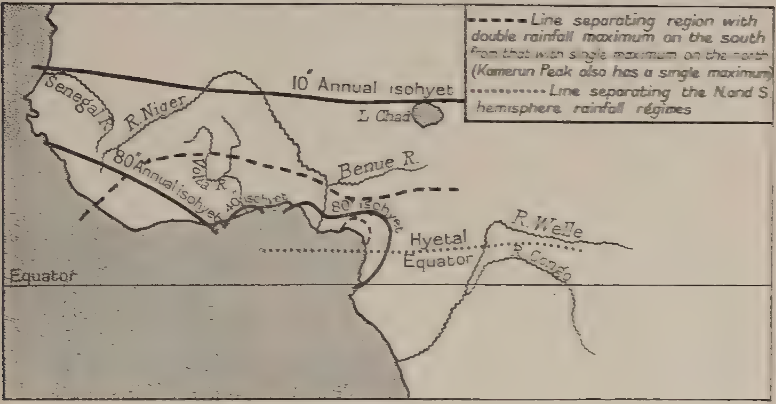

----Line separating region with double rainfall maximum on the south from that with single maximum on the north (Kamerun Peak also has a single maximum)
..........Line separating the N and S hemisphere rainfall régimes
10" Annual isohyet
L. Chad
Senegal R.
R. Niger
Benue R.
Volta R.
80" Annual isohyet
80" isohyet
Hyetal Equator
R. Welle
Congo
Equator

FIG. 11.

(Freetown, Fig. 12). This difference from the régime inland in the same latitude is doubtless due to the strong summer monsoon from the south-west meeting the elevated coast. The precipitation is greatest when the inflow is strongest, that is during the months when the interior is hottest (compare Kamerun Peak, p. 45). The rainfall is not so much convectional, with a maximum following each passage of the overhead sun, as orographical.

The total rainfall is very great, over 175 inches, in most of Sierra Leone ; most of it falls in the months April to November. The rainfall increases very rapidly on the coast from the Sahara southward. Cape Verde has about 20 inches, Bathurst 50 inches, Konakry almost 200 inches. The other specially rainy part of Upper Guinea, the Niger delta, has two maxima, occurring in June and October, but in every month of the year there is a considerable rainfall. At Akassa the driest month, January, has an average of 3 inches, and all other months have over 6 inches ; the wettest month is October, with 25 inches, and the yearly total is 144 inches.

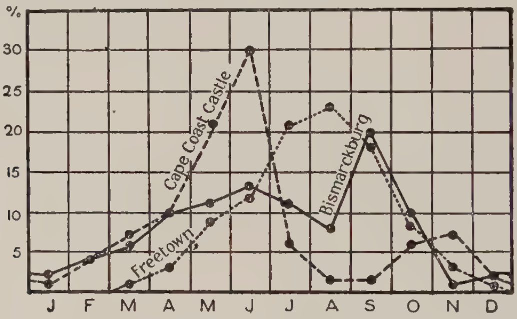


Fig. 12. Mean monthly Rainfall (percentage of yearly total) in the Guinea Lands.

Separating these two very rainy areas there is a narrow coastal strip between Cape Three Points and Nigeria with the remarkably small rainfall of about 30 inches (Fig. 11). Hereabouts the interior receives more rain than the coast ; fifty miles inland we find over 50 inches. The prevailing winds are the same on this drier strip as on each side, and the probable cause of the low rainfall is the existence in summer of an area of upwelling cold water off the coast, caused not by an off-shore wind, for the prevailing winds blow from the south-west, but by the pull of the Guinea current.

The cold water chills the wind as it passes over and diminishes its capacity for moisture. The frequency of fog supports this view.

The rain of the Guinea lands is of the equatorial type, most of it falling in very heavy showers between noon and midnight, generally accompanied by thunder and sometimes by tornadoes (see p. 37). During the whole rainy season the air is moist, often quite saturated, and there is much cloud.

The dry season presents a striking contrast. The prevailing north-east winds bring great drought especially when the Harmattan blows strong. The sky is almost cloudless, but yet far from clear, for the air is often full of a fine dust from the Sahara, producing a dismal dull grey which the sun can hardly pierce. Lake Chad is being slowly filled up by the dust blown into it from the north-east. The smoke from the enormous fires started by the natives to burn the dead savanna vegetation is another source of dull skies in the dry season.

The Harmattan is an east or north-east wind which blows direct from the desert and is extremely dry and dusty. It is almost constant in the northern part of the area during the dry season, less and less frequent farther south, but it occurs even on the Guinea Coast. Dryness is its most notable feature, humidities below 10 per cent. being observed. The leaves of the trees turn yellow and fall, wood splits, and man suffers great discomfort from the dry dusty air. Even this, however, is a relief from the steamy heat and on parts of the littoral the Harmattan has acquired the name of ‘ the doctor ’. It is usually described as a cold wind, especially at night. Probably the sensation of cold is due to the great evaporation from the observer’s skin, rather than to any specially low temperature of the wind. Thick fogs are frequent in the dry season on the Guinea Coast.

Temperature. In the hot season temperature is highest not in the south, where the sea reduces it though it provides the moisture which makes it so intolerable, but inland, where the mean for the warmest month exceeds 90°. In the dry season the interior is coolest, but even at Timbuktu the mean for January is over 70°. However, frost is not uncommon on the ground in the clear nights of the dry season, even as far south as Koury.

The mean annual range of temperature is greatest inland, being 23° at Timbuktu, and only 6° at Cape Coast Castle. The mean daily range is also greatest inland, at Timbuktu 31° in the dry season and 24° during the rains; at Grand Bassam it is 17° in January, 9° in July.

As in most monsoon countries the highest temperatures occur just before the rains begin, for when the rains are at their height the thick clouds cut off the sun's rays and the falling drops cool the air. A second maximum may occur when the rains cease. This is well seen at Timbuktu (Fig. 13), where May is the hottest month; the temperature falls decidedly till August and rises again after the rains have stopped—but not to the May figure. This town and the belt of country it represents in the north of our area, e. g. Senegal, may be said to have three seasons; (1) November to January, dry and cool, (2) February to May, dry and hot, and (3) June to October, the rains.

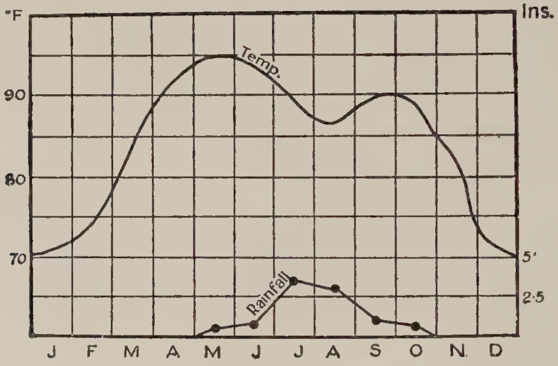


Fig. 13. Temperature and Rainfall at Timbuktu.

Along the coast, and indeed everywhere south of lat. 10° N., the drop in temperature in July and August is very marked, the means for these months being actually lower than those for December and January. But the mean annual range is small, considerably smaller than the daily range. The natives, enervated by the hot-house atmosphere, are very sensitive to temperature changes and light great fires to keep themselves warm at night.

It should be noted that very much higher temperatures are observed in the Sahara than in the Guinea lands where the clouds and moist air screen off the fierce rays of the sun. The highest shade temperatures ever observed on the Guinea Coast do not exceed 100°. Away from the sea, where the rains are shorter, higher maxima are recorded, and Timbuktu, with summer readings exceeding 118°, approaches very near to the furnace heats that prevail farther north. The unhealthiness of the Guinea Coast is due to the combination of excessive humidity with considerable heat, not to excessive heat.

Tornadoes. The most violent storms of the Guinea lands are called Tornadoes. They are thunder squalls which often start very suddenly, last but a short time, sometimes only a quarter of an hour, and may do considerable damage on land and sea. They almost always travel from east to west, and are specially frequent at the beginning and end of the rains. They are generally accompanied by exceedingly heavy rain and blinding lightning, but dry tornadoes also occur.

The tornadoes of the Guinea lands must not be confused with the storms of the same name in the U.S.A. These latter have, in general, less rain, and far more violent winds revolving rapidly with a short radius.

Nigeria. The climate of this large British possession, which bids fair to be of very great value in the near future, as the country becomes organized and developed, merits special description. Long series of meteorological observations are unfortunately few, except from the coast.

We may divide Nigeria into three belts. The northern includes all the country north of the central hilly region about 11° N. lat. This, the driest belt, experiences a very clearly marked monsoonal change of wind and weather. The seasons may be compared with those of the plains of India. December, January, and February constitute the cool season, but the mean temperature is as high as 70° in January. There is no rain. The usual wind is the Harmattan from the north-east, and since the desert is not far distant, it is very dry and brings much dust, so that clear air and bright skies are rare. Trees shed their leaves, and various other devices to check loss of water characterize the vegetation. Thorn bush is common.

In March the temperature rises fast and April, May, and early June are the hot season. The sun crosses the zenith and in May, as no clouds have yet appeared to screen it, the heat is intense, the mean temperature for the month being over 90°. The wind still blows from the north-east and the air is dry; there is some relief at night from the excessive heat of the daytime, so that the conditions are not unhealthy. June brings a decided change. South-west winds set in, with abundant cloud. The rains have begun. Violent dust-storms, 'dry tornadoes', mark the change of season. Temperature falls owing to the cloud canopy, and the range from day to night is less than in the previous months. The air is almost constantly saturated with moisture, and rain falls daily. Just as in the cool season Saharan conditions were in evidence, so now we have the weather of the Guinea Coast, with thunderstorms, tornadoes, and violent hailstorms. The rivers, many of which had quite dried up, roll along in heavy flood and much of Bornu becomes a great lake.

The rains last till September. The rainfall is least in the north, but even the northern frontier of Nigeria probably receives about 20 inches, and the Kano district about 30 inches. At the end of the rains, the temperature rises again as the sky clears. This is the most unhealthy part of the year, worse even than the rains. The rise in temperature is soon checked by the retreat of the sun to the southern hemisphere. By December the north-east winds are well established, and Europeans find life less burdensome.

The central belt comprises the country lying between the division just described and an arbitrary line which may be drawn at about 7° N. lat. The rainfall seems to be everywhere abundant, increasing from 40 inches in the north to 60 inches in the south. There are considerable differences in the altitude of the country. The valleys of the Niger and Benue, being only a few hundred feet above the sea, have less rain but much higher temperatures than the uplands; they are heavily forested in many parts, and unhealthy. The Bauchi plateau, 4,000 feet above sea level, is far cooler and has a healthy climate. The mean annual rainfall at Bauchi is about 40 inches. In this central belt the rains last longer than in the north, at Bauchi from May to September, at Lokoja from April to October; and the temperature is lower during the rains and higher in the dry season.

The third belt includes the rest of Nigeria. It is chiefly characterized by a very abundant rainfall, the rainy season extending over nearly the whole year, and by the small range of temperature. Most of the region is low-lying, the Niger delta forming a large part of it. Here we have the ‘West Coast’ climate in its most deadly form. The usual tropical mangrove swamp fringes all the innumerable creeks and streams, the trees growing out of fetid and pestilential slime which reeks with rotting vegetation. The climate is probably the most unhealthy in the whole world, an enervating moist heat day and night throughout the year. The prevailing winds are south-west, the Harmattan reaching the coast only occasionally in January and February. The temperature never falls below 60° at night, and usually remains between 70° and 90° throughout the twenty-four hours. The air is almost always charged with all the moisture it can contain. This constant damp heat weakens the strongest European constitution and leaves it a prey to malaria and the numerous other diseases fostered by the climate and the insanitary native villages. Very violent thunderstorms are frequent. The mean annual rainfall exceeds 120 inches along the sea-ward edge of the delta, and decreases northward to about 80 inches at Abo and 53 inches at Asaba. July and September are the wettest months. The higher land on both sides of the river probably has a heavier rainfall. March, April, and December are the hottest months, August the coolest, so that the usual seasons of the northern hemisphere are here reversed, owing to the dense cloud screen of the ‘summer’ months, but the difference between the mean temperatures of the extreme months is only 4°.

CHAPTER VII

THE SUDAN EAST OF LAKE CHAD; EGYPT

No long series of records have been kept in this region. The climatic belts which we have traced in West Africa probably extend right across the continent in very similar latitudes, the amount of rainfall becoming somewhat less, and the range of temperature somewhat greater, in the far interior.

Only as we approach the Nile do we find sure grounds on which to base description.

The Nile Valley, extending from south to north for more than 33° of latitude, is well equipped with meteorological stations in comparison with the rest of the continent, and as the valley passes through all the climatic belts from the Equator to the Mediterranean the records enable us to form a particularly instructive climatic 'section' of Africa which we shall now describe.

Egypt. The north coast, bordering on the Mediterranean, has a Mediterranean climate of an arid type—mild winters with a little rain and hot rainless summers (p. 23). The mean annual rainfall at Alexandria is 8 inches, and at Port Said 3 inches. Only a narrow coastal strip is included in this first climatic division. Already at Cairo we have reached desert conditions with an average annual rainfall of only 1 inch, all of it falling in winter. In spite of the lower latitude the winters are cooler than on the shores of the Mediterranean, but the summers are far warmer (Alexandria and Cairo, Fig. 14) and the air is much drier; the mean temperature at Cairo in January is 54°, about the same as in England in June. Although cyclones fail to give much rain, their effect is seen in the Khamsin winds that are a feature of all northern Egypt. They are strong south or south-east winds,

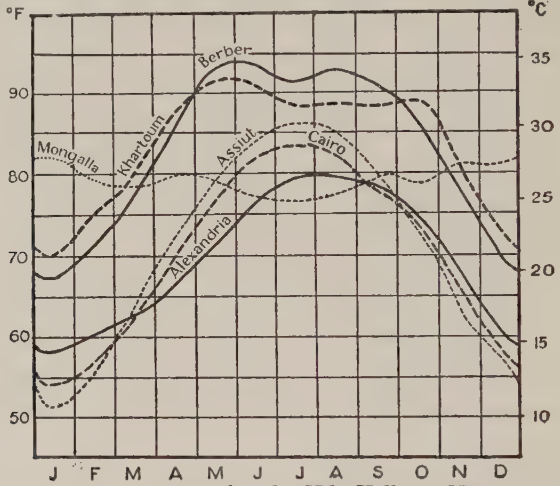


FIG. 14. Temperature curves for the Nile Valley. Note the influence of the Mediterranean Sea at Alexandria which is warmer in winter but cooler in summer than Cairo. The fall in temperature at Berber and Khartoum at midsummer is caused by the monsoon. Mongalla shares the equable conditions of the Equatorial zone.

caused by depressions passing off the delta or moving north-east from the Sahara towards the delta, and owing to the quarter from which they blow they are exceedingly hot and enervating; readings of 109° have been observed at Cairo; but in winter the south winds may be cooler than the normal. They carry much dust, so that the air is thick and yellow and the sun obscured. They usually continue for two or three days and are specially frequent in spring and early summer. At Cairo they blow on an average for eleven days in the year.

South of Cairo the desert conditions, already described for the Sahara, are more marked. Rain is almost unknown in this land of bright skies and brilliant sunshine. Temperature is very extreme. At Wady Halfa 126° has been recorded in summer and 34° in winter. Berber is situated in the hottest region, and here the average maximum temperature which must be expected on a June day is 112°—the highest in the Nile Valley; the average minimum on a January night is 49°. Naturally, the winter nights are colder farther north, the lowest January minimum recorded being at El Skeikh Fadl (between Cairo and Asyut). Beyond this the warmth of the Mediterranean Sea prevents any further fall. Alexandria is 6° warmer than Asyut in January (Fig. 14).

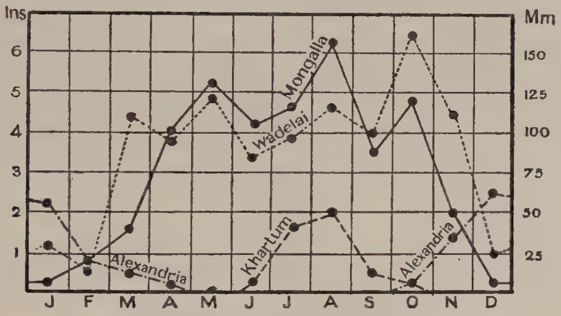


FIG. 15. Rainfall in the Nile Valley.

At Cairo and in the Nile Valley south of it the prevailing winds throughout the year are northerly, so strong and constant that Nile boats make the journey upstream more easily than down. But a change begins at Meroe, which has a short spell of southerly and variable winds in July and August; we are approaching the Sudan with its monsoonal indraught of which we have traced the western section in the Guinea lands. The transition from

Sahara to Sudan is rapid. At Khartoum, only 100 miles south of Meroe, south-west winds are predominant from June to September and give 5 inches of rain, the dry north-east trades holding sway for eight months. The climate is not unlike that of Timbuktu, but drier.

South of Khartoum the rains become heavier and last longer, from April to October at the junction of the Bahr-el-Ghazal and the Nile. Mongalla (5° N. lat.) is still in the region of summer rains, but two maxima appear in the rainfall curve. The two maxima become more and more pronounced southward till at Wadelai (3° N. lat.) we find equatorial conditions, rain all the year, with maxima in May and October (Fig. 15).

The change from desert to Sudan is less obvious to the traveller in the Nile Valley, since the Nile forms a continuous oasis. The date palm is cultivated from the Mediterranean coast to Khartoum. The finest fruit is got between Cairo and Aswan, luscious dates which can be easily dried for export ; to the north the air is rather too damp, to the south too hot and dry.

CHAPTER VIII

ABYSSINIA AND SOMALILAND

Abyssinia. This plateau attains an altitude of over 15,000 feet, and is within the reach of the monsoon winds from the south. It therefore has a heavy rainfall in summer, which suffices to flood the Nile Valley for 1,200 miles through the desert. The fertility and civilization of Egypt are thus to be attributed to the summer rains of Abyssinia.

The rainfall brought by the monsoon decreases towards the north till it ceases where the Sahara begins. Abyssinia is situated about this northern limit, and hence, but for the influence of the mountains, there would be but little rain. The rainfall is of the usual tropical mountain type, falling generally in violent thunderstorms. It is considerable in April and May, and in the extreme south in February and March also, but the heaviest rains are from June to October. The total amount varies from about 70 inches in the south to 50 inches round Addis Ababa, 40 inches round Gondar, and 20 inches in the Mareb basin. The rainfall is less than on the Lake Plateau of East Africa, but there it is distributed over the whole year, while in Abyssinia it is concentrated into a few months, and hence is much more effective in flooding the rivers.

The exact place of origin of the monsoon winds which bring Abyssinia its rain has not yet been established with certainty. Geographical considerations would incline us at first to suppose that they blow from the south-east, that is to say from the Indian Ocean. But the isobars for July (Fig. 4) over the Sudan show a definite gradient for south-west, not south-east, winds, the Sahara forming one vast low-pressure area with south Asia. Moreover, the prevailing winds in Abyssinia at the height of the rains appear to blow from the south-west, though it must be remembered that the records are few, and only for short periods; moreover, the mountain valleys may modify the general air currents. A recent theory maintains that in April and May a low-pressure system develops over the upper and middle Nile Valley owing to the increasing heat as the sun enters the northern hemisphere, and the winds blow from the south-east over Somaliland to Abyssinia, into the low-pressure area, and bring the early rains; but with the advance of summer the low pressures over the Nile Valley become merged in the great low-pressure system which extends west from India, and after a few weeks of variables a definite south-westerly current appears in obedience to the new pressure gradient, and it is this current which brings the heaviest rains to Abyssinia in June, July, August, and September. (See *The Rains of the Nile Basin.* Cairo, 1913.)

The natives of Abyssinia distinguish three climatic zones:

(i) The Kolla, lowland up to 6,000 feet, consisting largely of valley bottoms, which have the uniform high temperatures of the Sudan; May and October are the hottest months.

(ii) The Voina Dega ('wine highland'), 6,000 to 8,000 feet, much cooler.

(iii) The Dega ('highland'), over 8,000 feet, still colder. Cereals are cultivated up to 12,700 feet.

We may add to these another region:

(iv) The eastern plains, including Eritrea, bordering the Red Sea. Here the air is moist, but the rainfall is scanty (Massaua, 7 inches) and most of it falls in winter, though the summer monsoon also brings a little. The mean annual temperature at Massaua is 86°, one of the highest recorded on the globe; the warm sea prevents cool winters and cool nights, but the midday heat is not so intense as in the interior.

Somaliland, British and Italian. Most of the peninsula known as the Horn of Africa consists of plateau with an elevation of from 1,000 to over 6,000 feet. The coastal plain is only some 15 miles wide along much of its length on the Gulf of Aden, and it is bounded sharply by the steep edge of the plateau. The descent from the plateau is less abrupt towards the Indian Ocean and the coastal plain is wider. The coast is very arid, but the rainfall exceeds 20 inches in parts of the interior. The monsoonal wind reversal is strongly marked, the north-east monsoon blowing from October till May, the south-west monsoon in July and August, with great regularity; in June and September the winds are variable. The few records available show that the coast of the Gulf of Aden receives nearly all of its scanty rainfall in the months January to May from the north-east monsoon, which is forced to precipitate some of the moisture it has picked up during its passage across the gulf as it rises towards the plateau; but the annual total at Berbera is only 2 inches. The plateau on the other hand gets its rain in summer, from April to November, mostly from the south-west monsoon, as in the case of the Sudan farther west. But the shores of the Indian Ocean are almost rainless, for the winds blow parallel to the coastline and the edge of the plateau, and consequently there is no ascent. Still more arid in summer is the coastal plain along the Gulf of Aden, to which the winds have to descend from the elevated interior.

The coastal plain of British Somaliland is extremely hot, the mean annual temperature at Berbera being 85°. In July the mean temperature is 97°, the mean daily maximum 107°, the mean daily minimum 88°, and even in January, which has a mean of 76°, the mean daily minimum is 69°. During the summer months especially the air is very dry and often dust-laden. The coast of Italian Somaliland is cooler in summer owing to the wind blowing more frequently from the sea; moreover, there appears to be a belt of upwelling cool water along the coast, which would account for the fogs that sometimes occur. The highest parts of the plateau are comparatively cool owing to the altitude. At Sheikh, 4,500 feet above the sea, the mean temperature is about 75° in July, 60° in January.

CHAPTER IX

KAMERUN

The climate resembles that of similar latitudes and altitudes in Nigeria, already described. The southern part of Kamerun, however, extends almost to the Equator, and therefore has certain peculiarities. The extraordinarily heavy rainfall is noteworthy. The west side of Kamerun Peak has 412 inches per annum near sea level; this is the second highest record in the world, surpassed only at Cherrapunji (India) which has 458 inches. The rainiest months are June, July, August, and September. The single maximum in the rainfall curve is an interesting variation from the double maximum which is usual along the Guinea Coast, and it is doubtless an effect of the lofty mountain (compare Sierra Leone, p. 34). The prevailing winds throughout the year are westerly. This monsoonal inflow is strongest in the late summer of the northern hemisphere when the temperature in the interior is highest, and hence the rainfall, which is largely due to the ascent of the winds up the mountain, is then heaviest. The driest months are January and February, but even then there is considerable rainfall.

The parts of tropical Africa described up to this point have shown general agreement in having their rainfall during the summer of the northern hemisphere. In the south of Kamerun at about lat. 3° N. we find the rainfall 'Equator' (Fig. 11), where rain falls throughout the year, with two well-marked maxima at the equinoxes. South of this we enter the rainfall régime of the southern hemisphere, that is to say, the months October to April are the wet season, May to September the dry. At Libreville on the Gabun River, slightly north of the geographical Equator, the conditions are decidedly those of the southern hemisphere, the rains commencing in September and lasting till May, with maxima in November and March; June, July, and August are practically rainless.

The mean annual rainfall at Libreville is 96 inches. As we go farther south along the coast the régime remains much the same, but the amount becomes less and less from Kamerun to South-west Africa. Banana, at the mouth of the Congo, has only 29 inches.

The low rainfall of this coast is due primarily to the prevailing south-east trades, and the resulting upwelling cold water off the shore. The winds actually observed on the coast are generally westerly, but these are merely the local sea breeze, which affects only the coastal strip, and, blowing over a comparatively cool sea, brings little if any rainfall. The rainfall on the coast and islands near the Equator and the estuary of the Congo is very variable in amount from year to year. The temperature, too, shows considerable variations. The explanation is probably to be found in the oceanic conditions. The sea off this coast is a debatable area, now reached by the Benguela current, now by the Guinea current. When the cold Benguela current is present the temperature is low and the rainfall scanty, but when it is replaced by the warm Guinea current there is higher temperature and more rain.

CHAPTER X

THE CONGO BASIN

The western part of this region round the mouth of the river has just been mentioned. Its low rainfall especially distinguishes it from the rest of the basin. It enjoys, too, the advantage of a regular sea breeze, a valuable alleviation of equatorial conditions for white settlers, against which, however, we must set the unhealthy swamps.

The remainder of the state consists of a vast basin generally some 1,000 to 1,600 feet above the sea, enclosed by the higher plateau of the continent.

The climate is equatorial. The mean difference in temperature between the warmest and the coolest months is extremely small, only about 4° F. in the central area. The warmest month is February or March when the rains are at their height, the coolest August in the dry season, the transition from the rains to the dry season being marked everywhere by a fall in temperature (contrast the Sudan, p. 36). The range of temperature from day to night is far greater than that from season to season. Thus at Bolobo the mean daily range is 16°, but the difference between warmest and coolest months is only 2°. The highest temperatures recorded are by no means so high as those in the deserts of higher latitudes. At Equatorville no reading above 95° has been known and readings above 90° are unusual. The minima also fail to touch those recorded in the clearer and drier air to the north and south; at Equatorville 63° is the lowest on record. It is not so much excessively high temperatures, as the combination of great humidity and considerable heat, and the monotonous continuation of such hot-house conditions throughout the year, that are so trying to the European in an equatorial climate. However, Sir H. H. Johnston says that the climate of the Congo 'on the whole may be said to be infinitely superior to that of the Niger or the Gold Coast. The great absence of low marshy ground about its banks is doubtless the cause of less virulent fever, and the regular cool breezes from the South Atlantic greatly reduce the tropical heat. The river probably is least healthy between Boma and the sea, owing, no doubt, to the mangrove swamps. Boma itself is decidedly insalubrious. It is the hottest place on the Congo and surrounded by many marshes. Towards Vivi it becomes decidedly cooler, owing to the greater elevation; and the higher you proceed up the river the healthier the climate becomes'.

The mean annual rainfall varies from about 50 inches in the south to a little over 70 inches. Thus it is notably less than in the same latitudes in the Amazon Basin. South America lies open on the east for the entry of the south-east and north-east trade winds, while the Andes close in the basin on the west and force the trades to ascend and deposit copious rain. The Congo State, on the other hand, is surrounded by high ground, which forms a considerable barrier especially on the east; the winds that enter it from the west have come over the cold Benguela current, and hence do not produce very much rain.

There are three rainfall régimes (Fig. 16). In the north, along the Ubangui, where that river runs in an east to west direction, and the Welle, the régime is that of the northern hemisphere (see Fig. 11); there is heavy rainfall in every month from March to November inclusive, the rainiest months being June and September; the period December to February is the dry season, January being rainless. The annual rainfall at Mobaye on the Ubangui is about 65 inches. We have here the transition from equatorial to Sudanese conditions.

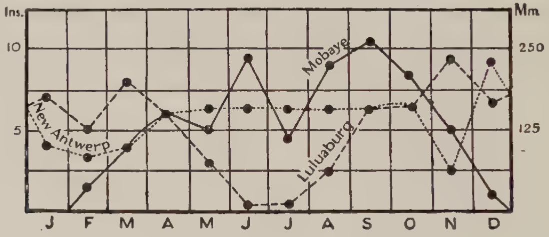


Fig. 16. Rainfall of the Congo Basin.

About lat. 2° N., along the northernmost bend of the Congo River, there is an equatorial rainfall régime, every month being rainy as at New Antwerp. South of this the régime is that of the southern hemisphere. At Equatorville, on the Equator, the driest month is July, the rainiest November and December, but rain falls throughout the year. At Brazzaville on the Congo (lat. 4° S.) there is a pronounced dry season, June to September. At Luluaburg (lat. 5° S.) far in the interior the dry season is shorter, only June and July being rainless (Fig. 16). Thus the southern part of the basin receives its rains while the northern part is dry, and vice versa, and in consequence the lower Congo River has two periods of flood in the year, one in December and the other in April and May.

The rain is of the thunderstorm type, and during the rainy season there is a downpour practically every afternoon and evening. The dry season is rendered unpleasant by frequent thick fogs; the sky is usually grey, gloomy, and cheerless, and the air is often thick with smoke from the numerous grass fires, started by natives in the savannas to clear the ground of dead vegetation.

> 'The great fault of the climate lies in the excessive damp. Even in the dry season there is great moisture in the air, for, though there is no downright rain, yet the mornings and evenings are ushered in by dense white mists, like low-lying clouds, which incessantly filter through the clammy atmosphere a drizzling vaporous spray that descends over everything like a heavy dew. This is the "cacimbo" of the Portuguese colonies and the "smokes" of the Guinea Coast. These morning and evening mists are characteristic of the dry season, and during the rainy months they disappear, and the beginning and closing of the day is generally bright and clear.' (SIR H. H. JOHNSTON.)

In the east of the Congo State the prevailing winds in the dry season are south-east. During the rains there are calms and variable winds largely from the west, since a low-pressure system covers South Africa. In the west the prevailing winds are west and south-west. The sea breeze is of almost daily occurrence, setting in at Boma about 1 p.m. and attaining its greatest force, that of a strong breeze, at sunset. The land breeze that sets in some hours later is much weaker. In the Congo Valley far above the estuary the sea breeze is still felt, but a more striking phenomenon is a strong squall which blows up at or just after sunset from the west or north-west, and dies down again after about half-an-hour. Sometimes the wind increases again from the same direction later in the evening. These night winds which, contrary to the usual rule in the tropics, are stronger than the afternoon sea-breeze, are specially characteristic of the dry season. They occur in Loanda and elsewhere in West Africa. Their origin is not understood.

The storms of the Congo are thunderstorms and tornadoes similar to those of the Guinea Coast, most frequent at the beginning and end of the rains. As on the Guinea Coast they almost invariably come from the east.

The extreme south of the Congo State, Katanga, is on the South African plateau, much of it at an altitude of 5,000 feet. In respect of climate it resembles Northern Rhodesia (p. 64) rather than the rest of the Congo Basin.

CHAPTER XI

KENYA COLONY (BRITISH EAST AFRICA) AND UGANDA

Our possessions lie astride of the Equator, but the ordinary equatorial type of climate is modified to such an extent by the altitude of the country that wide areas of upland enjoy a healthy and pleasant climate, and offer a favourable field for European settlement and colonization. The highest mountains are even snow-capped throughout the year, and Kenya, situated right on the Equator, has several small glaciers. So anomalous did this seem when the country was first explored that geographers at home refused to believe the early travellers who reported perennial snow in the torrid zone, and they tried to explain away the white cap the pioneers claimed to have seen from afar.

During the summer of the southern hemisphere when the lowest pressures are over South Africa, the wind over East Africa generally is north-east. From May to October the summer monsoon of North Africa and Asia is the dominating factor, and the prevailing winds are from the south-east. The transition months are the rainy seasons, with weak variable winds and an overhead sun. The rain is of the equatorial type, falling in violent thunderstorms in the afternoon and evening. In general the major rainy season is February to May, the minor October to December, but in much of the country there is a considerable rainfall in every month of the year. June to September is the chief dry season ; January and February are drier months than those before and after, but in many districts they are too rainy to justify the title of dry season. The rainfall is very variable from year to year both in amount and season.

Temperature varies in the usual way with altitude but has everywhere the characteristic of great uniformity throughout the year. In this we have an important difference from European conditions even in those parts of East Africa where the altitude reduces the mean annual temperature to that of the temperate zone. Thus Fort Smith (Kikuyu), 6,700 feet above the sea, has a mean annual temperature of 61° (compare Lisbon, 60°), but the difference between the mean temperatures of the warmest and coolest months is only 8° (at Lisbon, 21°). At Mombasa, on the coast, the mean annual temperature is 78°, the mean annual range 6°.

The climate belts are the topographical belts which run north and south, roughly parallel with the coast line. The data available are quite insufficient to render a strict delimitation of the various belts possible, but we attempt in Fig. 17 to sketch the main climate divisions of East Africa, which are described in this and the following chapters. They are subdivided *a*, *b*, and *c*, *a* denoting northern hemisphere régime of rainfall and temperature, *b* equatorial, and *c* southern hemisphere. The divisions are:

1. The coastal plain.
2. The arid east of the plateau.
3. The middle plateau from 4,000 to 6,000 feet above sea level.
4. The high plateau, including the Athi, Kapti, and Leikipia plains on the east of the Rift Valley and the Mau escarpment on the west. This is the most suitable belt for white occupation.
5. The eastern Rift Valley.
6. The moist lake and river-valley climate with small range of temperature; malarious, and generally unhealthy for whites. This division includes the western Rift Valley.
7. The mountains, with heavy rainfall.
8. The hot and comparatively dry north-east shore of Lake Tanganyika.

The coastal plain (1, Fig. 17) includes the strip of low ground varying in width up to about 15 miles, and running much farther up the river valleys. It has the usual equatorial climate, hot, moist, and unhealthy, except in the north. The rainfall is greatest in the south, the neighbourhood of Mombasa having over 45 inches; this is one of the wettest parts of the Colony. The rainiest periods are April to July and November, the driest January and February. Towards the north the rainfall diminishes. Kismayu on the Equator near the mouth of the Juba has only 15 inches, and with the neighbouring parts of the Colony, shares the arid conditions of Somaliland; there is a single rainy season, April to July.

The next belt towards the interior (2, Fig. 17) consists of the lower part of the plateau, the Nyika, usually described as a desert belt, except during the rains. ‘The grasses and sedges in this part grow in little tufts, at some distance from one another, leaving the general tint of the landscape that of the soil itself. No sward or turf is formed, and, except immediately after the rains, all these grasses are dead, dry and withered up. Most of the plants are either thorny or fleshy as is usual in all desert countries.’ This is the type of country passed through by the Uganda Railway between Samburu, 40 miles from Mombasa, and Maungu, 40 miles farther west. It is known as the Desert of Taru, and extends north into Somaliland, south into Tanganyika

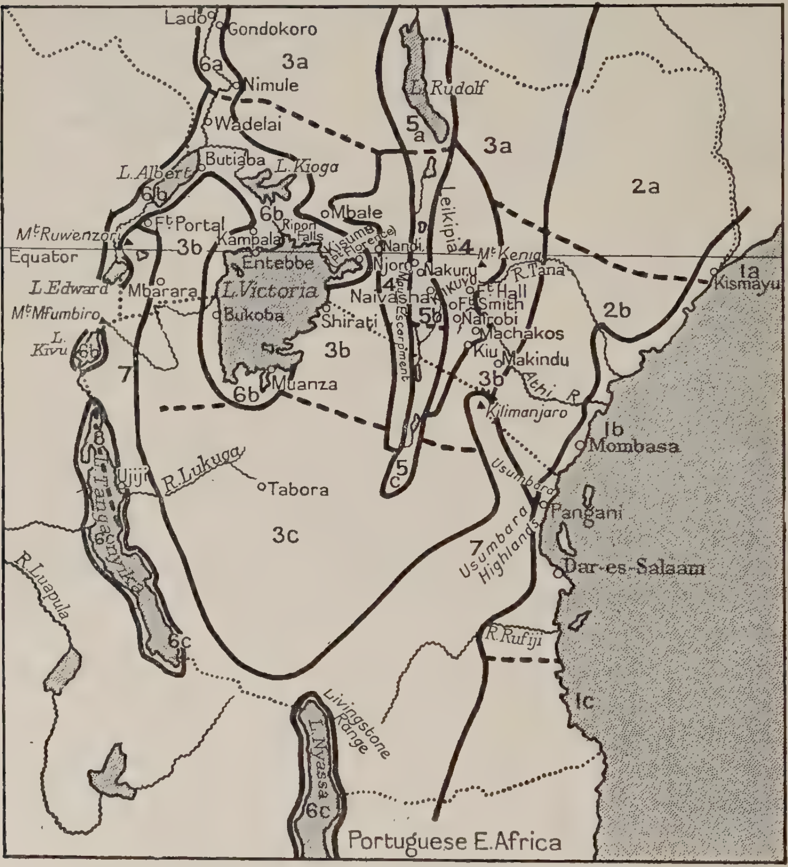

Lado
Gondokoro
3a
6a
Nimule
L. Rudolf
Wadelai
5a
3a
2a
L. Albert
Butiaba
L. Kioga
6b
Mbale
6b
Ripon Falls
Ft Portal
Mt Ruwenzori
3b
Kampala
Kisumu (Pt Florence)
Nandi
Leikipia
4
Mt Kenia
Equator
Entebbe
Njoro
Nakuru
R. Tana
1a
Kismayu
L. Edward
Mbarara
L. Victoria
4
Naivasha
Kikuyu
Ft Hall
Ft Smith
Mt Mfumbiro
Bukoba
Shirati
Mau Escarpment
5b
Nairobi
2b
Machakos
L. Kivu
6b
3b
Kiu
Makindu
7
6b
Muanza
3b
Athi R.
Kilimanjaro
1b
Mombasa
8
5c
Ujiji
R. Lukuga
Tabora
Usumbara
Pangani
L. Tanganyika
3c
7
Usumbara Highlands
Dar-es-Salaam
R. Luapula
6c
R. Rufiji
1c
Livingstone Range
L. Nyassa
6c
Portuguese E. Africa

FIG. 17. The major climate regions of East Africa.

Territory. The altitude is about 1,000 feet. The rainfall seems to be about 25 inches a year in the part traversed by the railway. The aridity of the belt is due partly to the low rainfall, partly to the permeable soil. The sea is too distant to provide the heavy fall received at Mombasa, and the altitude is not great enough to remedy the deficiency. The drought, the inhospitable vegetation, and the ubiquitous dust were serious obstacles to the penetration of the interior of equatorial East Africa, before the construction of the railway.

The plateau continues to rise (3, Fig. 17) to the westward of the Taru country and the temperature falls, to the eastern edge of the Rift Valley where the general altitude is about 8,000 feet. Rainfall becomes more abundant, and as the temperature is lower the rain is more effective for plant life. Above about 4,500 feet, that is to say along the railway line above Kiu, the climate is well suited for Europeans, and the Leikipia, Kapti, and Athi plains especially offer very favourable conditions for white settlement (4, Fig. 17). The Kikuyu hills are said by their admirers to enjoy a climate which has hardly an equal in the world for white men. The mean annual rainfall is 39 inches at Nairobi, 48 inches at Kikuyu. Rain falls in every month of the year, the chief rainy seasons being February to May, the 'maize rains', and October to December, the 'millet rains'. The chief dry season is July to September (Fig. 18). As is to be expected on a plateau the days are hot, and the nights cool, especially in the dry season, the thermometer often rising to 80°, and falling to 45°, but seldom showing more extreme readings. The mean annual temperature at Nairobi, 5,450 feet above the sea, is 63°; the mean difference between the warmest and coolest months is 7°. It will be noticed that the proximity of the Equator makes itself felt in the small annual range (Fig. 18). The highest temperature recorded here during 5 years was 88°, the lowest 36°. On the highest part of the plateau frost occurs but is never severe.

Mount Kenya is a great volcanic mass rising from the plateau, here about 6,000 feet above the sea, to an altitude of 18,620 feet. The southern slopes receive heavy rain, hail, and snow, especially during the months April to June and September to November. The northern side of the mountain is much drier. A belt of forest clothes the slopes between 5,500 and 12,000 feet, except on the northern side where there is grass land. Between the forests and the cap of perpetual snow is a zone of alp, pasture land with drought-resisting bushes; above this come mosses and lichens, and above 16,000 feet snow lies throughout the year, despite the equatorial sun, and is abundant enough to maintain fifteen small glaciers. The climate zones on Mount Kilimanjaro are similar.

The plateau descends from Kikuyu very steeply into the eastern Rift Valley (5, Fig. 17), some 2,000 feet below, a long trench running north and south for hundreds of miles. The northern part of it, including Lake Rudolf, is about 1,300 feet above sea level. The rainfall is probably scanty, and the valley is described as having a desert appearance. Similarly arid conditions seem to prevail over much of the northern part of the Colony, north of 2° N. lat., except in the Nile Valley and on the mountains. The central part of the Rift Valley, where it is crossed by the railway, is much higher. Lake Naivasha is 6,230 feet above the sea, i. e. more than 2,000 feet above Victoria Nyanza. Here the rainfall is greater than in the northern part of the valley, 32 inches per annum at the town of Naivasha, 33 inches at Nakuru, but less than on the plateau. March to June, and October and November have most rain, January and February least, but no month is rainless. The air is bracing. This part of the Rift Valley is said to be specially suitable for sheep-rearing.

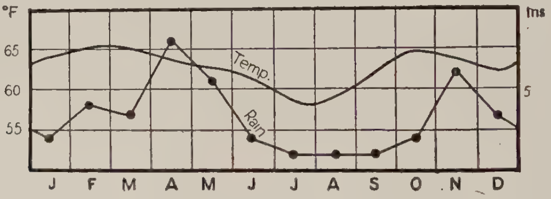


FIG. 18. Mean Temperature and Rainfall at Nairobi.

South of Mount Longonot the floor of the Rift Valley sinks, and the climate becomes warmer, still with a low rainfall.

The tendency to aridity in the Rift Valley finds expression in the fact that it is everywhere a region of inland drainage.

The western boundary of the Rift Valley is the steep Mau escarpment, corresponding to Kikuyu on the east. The lower slopes round Njoro have a climate that suits wheat excellently. The top of the Mau escarpment (4, Fig. 17) where the Uganda railway crosses it is 8,320 feet above the sea, slightly higher than the edge of the Kikuyu plains and enjoying a similar climate. The annual rainfall near the railway is 40 inches ; at Nandi near Lake Victoria it is 68 inches.

The land slopes down westward to Victoria Nyanza, 3,840 feet above the sea. About 200 miles long and 250 broad, the lake is large enough to exert much influence on the climate of the neighbourhood (6, Fig. 17). There are well-marked land and sea breezes on its shores. During the season of the south-east winds the land breeze at night at the south end of the lake, blowing in the same direction as the main air current, is specially strong, and is very dry. At the north end of the lake, however, it is the sea breeze that is reinforced, and moist air and considerable rainfall are the result, even in the dry season. Violent storms of wind are not uncommon on the lake, and native canoes are glad to hug the shores. Waterspouts are often seen. Daily thunderstorms of great intensity occur during the rains in the afternoons ; indeed almost all the rain is of the thunderstorm type. Every month of the year is rainy on the northern shores ; July and August least so. At Port Florence the annual rainfall is 45 inches, at Entebbe 58 inches. The air is moist, temperature fairly high and very uniform, the annual mean being about 70°, and the difference between the warmest and coolest months only about 4°. The highest temperature that has been recorded at Entebbe is 90°, the lowest 55°. The west shore of the lake also is moist, the east and south far less so, much of the country being poor steppe (3, Fig. 17). Bukoba, on the west shore, has a mean annual rainfall of 76 inches, Shirati, on the east shore, 27 inches.

Much of the rainfall of the lake shores is the product of evaporation from the lake surface. Away from the lake the rainfall diminishes, and the range of temperature increases (3, Fig. 17), but towards the west only a narrow strip of country intervenes before the rise of the plateau surface, as the edge of the western Rift Valley is approached, introduces new conditions (7, Fig. 17) culminating in the mountain climate of Mfumbiro (14,800 feet) and Ruwenzori (18,700 feet). The climate zones here are similar to those on Mount Kenya. The rainfall is heavy throughout the year. It is estimated at over 160 inches on the west slope of Ruwenzori. At Fort Portal on the north-east base of the mountain the annual rainfall is 57 inches. The whole mountain is often hidden in mist for weeks together. Above 14,000 feet there is perpetual snow.

The western Rift Valley (6, Fig. 17), about 3,000 feet above the sea near Ruwenzori, is swampy and unhealthy, the abundant moisture being due both to the drainage from the rainy mountains on both sides and to the rainfall in the valley itself caused by their proximity.

North from Lake Victoria the rainfall diminishes steadily down the Nile Valley away to the Sahara. At Ripon Falls it is 46 inches, at Wadelai (Nile Valley) 43 inches, at Mongalla 39 inches. At Wadelai we are already approaching the conditions of the Sudan, and at Mongalla we have the typical Sudan features well marked, a dry season from November to March, and a considerable range of temperature.

In general Uganda is unhealthy for Europeans, especially in the swampy lower lands such as the shores of Lake Victoria, in the western Rift Valley round Lake Kioga, and in the Nile Valley, all of which are malarious. Only small parts of the higher land in the west appear to have any possibilities for European settlement.

The following table, showing the mean diurnal range of temperature at stations representative of the various altitude zones, presents features of interest :

		Mean Diurnal Range of Temperature °F.		
	Altitude. Feet.	*Annual.*	*Month with greatest range.*	*Month with least range.*
Mombasa . .	50	10	(Jan.) 11	(May) 9
Nairobi . . .	5,450	22	(Jan.) 27	(May) 17
Eldama Ravine .	7,240	28	(Oct.) 35	(Feb.) 25
Kisumu . . .	3,800	20	(Jan.) 21	(Apr.) 15

It will be noted that the greatest range occurs during the dry season, the least during the rains. It is interesting to observe how the range increases as the sea is left behind and higher elevations are reached, and then decreases again on descending to the shores of Lake Victoria at Kisumu.

Mean Annual Rainfall at Stations in Uganda, in addition to those given on page 87.

	Altitude in Feet.	*Inches.*
Nimule	2,034	42
Mbarara	4,500	73
Fort Portal	5,299	57
Butiaba	2,025	33
Kampala	3,905	49
Mbale	4,000	51

[The isohyets over East Africa in Fig. 7 show some discrepancies from the statistics given in this chapter.]

CHAPTER XII

TANGANYIKA TERRITORY

This region, like its neighbour Kenya Colony, is for the most part a plateau, and its climate has the usual plateau characteristics. But in general its surface is lower and of a more uniform elevation. Moreover, being entirely in the southern hemisphere, between lats. 1° and 11½° S., it has greater seasonal changes.

The monsoonal wind reversal from north-east, when the sun is in the southern hemisphere, to south-east or south-west during the northern summer is well marked, especially on the coast. In general south-east or south-west winds prevail from May to October, north-east from mid-November to mid-March. During the months of change of monsoon there are light and variable easterlies and calms; these are the times of heaviest rainfall. But the south of Tanganyika Territory is near the southern limit of the north-east winds (see p. 15), which have but little force here even in January when they are at their strongest. Indeed the winds may best be described as variable in direction, but predominantly from the north during the southern summer, the whole of which is the rainy season.

In the north the climate round Lake Victoria (3 and 6, Fig. 17) resembles that of Uganda, but has a considerably smaller rainfall. Kilimanjaro presents a series of climate zones similar to those of Mount Kenya. The eastern Rift Valley (5, Fig. 17) continues south as a notable feature. The coastal plain (1, Fig. 17) is narrow in the north, but widens towards the south to more than 200 miles in many parts. It resembles the corresponding part of Kenya Colony in being hot, wet, and unhealthy. West of it rises a more or less continuous belt of elevated ground (7, Fig. 17) which includes the Usumbara Heights in the north and the Livingstone Range overlooking Lake Nyasa in the south-west; this is the elevated eastern edge of the plateau of which most of the country consists. The coastal plain and the eastern heights receive a heavy rainfall from the winds that blow off the sea. Most of the coastal plain receives over 40 inches per annum, the northern part over 60 inches. Probably the eastern slopes of the highlands have more than 100 inches. The Livingstone Range, with altitudes of 10,000 feet, is continued by a line of considerable, though inferior, height between lakes Nyasa and Tanganyika. Here too the rainfall is very abundant, 100 inches in places, much of it derived perhaps from the waters of Lake Nyasa, over which the south-east winds blow before their ascent to the highlands.

The shores of Lake Tanganyika also rise to considerable elevations, and have abundant rainfall, probably about 50 inches.

The rest of the Territory, including the Unyamwezi country, consists of a plateau 3,000 to 5,000 feet above the sea (3, Fig. 17) more or less enclosed by the higher lands just mentioned. Hence its rainfall is comparatively small, in general under 35 inches; Tabora has 33 inches. The vegetation is poor steppe over considerable areas. The effect of the eastern heights on the rain-bearing winds is seen in the fact that the windward eastern slopes of the Usumbara highlands have over 80 inches of rain, the leeward slopes only 30 inches per annum.

The eastern shores of Lake Victoria are much drier than the western, since the prevailing winds are from an easterly point most of the year. Shirati gets only 27 inches of rain per annum, Bukoba opposite it on the west shore as much as 76 inches. Further details of the climate of the lake shores have been given already (p. 55).

Around Tanganyika also the highlands on the west shore have a heavier rainfall than those on the east; the strip of low land along the east shore of the lake (8, Fig. 17) is a well-marked rain-shadow; Ujiji receives only 33 inches per annum.

In the north of Tanganyika Territory there are two rainy seasons in the year, February to April and October to December (equatorial régime) as at Muanza; the chief dry season is June to September when the sun is in the northern hemisphere, and the dry south-east trades are sweeping the country, but July is generally the only month with less than 1 inch of rain. The farther south we go, the longer and drier is the dry season. The two rainy seasons come nearer together, and in the extreme south they coalesce to form a single rainy season during the southern summer, the effect of the zenithal sun being shown by an increase in the rains in December—January and March—April. At Tabora and in most of the interior south of it, except the mountains, July and August are quite rainless, and the whole period from May to October is decidedly dry; November to April is the rainy season. The change from heavy clouds during the rains to abundant sunshine in the dry season is similar to what has been described for the Sudan.

In the coastal belt not only are the rains heavier but they also last longer than inland. Even in the extreme south there is no rainless month; June to November is the dry season. At Pangani, in the north, the rains comprise the months March to May, and October to December, but none of the intervening months has less than 1 inch of rain.

The chief characteristics of the temperature, as modified by altitude and distance from the sea or great lakes, have been pointed out in our description of Kenya Colony. In the north, especially on the coast and near Lake Victoria, there is great uniformity throughout the year. Farther from the Equator November is generally the warmest month, before the summer clouds and rain cool the air. June and July are coolest. The mean temperature is remarkably similar everywhere when allowance is made for differences of altitude.

CHAPTER XIII

ANGOLA

Angola, lying between 6° and 17° S. lat., may be regarded as a transition region between the rainy Congo State and arid South-west Africa. The rainfall diminishes from north to south and from east to west. The rainy season is October to April, the passages of the sun overhead causing two maxima, which occur in December and March. May to August is an almost rainless period.

The two main divisions of the country are the coastal strip, generally some 60 miles wide, and the interior plateau, as much as 7,000 feet high in the west, and descending gently to 4,000 feet in the east.

The coastal strip is distinguished by its scant and uncertain rainfall, 20 inches in the north, and less than 10 inches in the south. The aridity is caused partly by the cold Benguela current, from over which the prevailing south-west and west sea-breezes bring much fog and cloud but little rain, and partly by the position of this coastal strip at the foot of the interior plateau, so that winds reaching it from this direction are descending and therefore dry. The mean annual temperature at Loanda is 74°, lower than that at Luluaburg, 2,000 feet above the sea in the Congo Basin, in about the same latitude, which has 76°. The cold current on the coast more than neutralizes the less altitude of the former station.

The rainfall on the plateau probably exceeds 40 inches everywhere. The mean annual temperature is about 68° where the altitude is 4,000 feet. The rise in temperature in summer is checked by the rain and clouds, so that the warmest months are October and January. The coolest and clearest months are May to September, and then, especially in the south, frost is common at night owing to the great radiation on the plateau. The air is then often very dry, but at times clouds and heavy mists, ‘ cacimbo ’, make their appearance.

CHAPTER XIV

SOUTH-WEST AFRICA

As far north as the Congo mouth we have noticed a tendency to low rainfall on the coast. This tendency becomes more and more pronounced southward to South-west Africa.

The prevailing winds are the south-east trades (masked on the coast by the almost constant sea-breeze), which, having blown across the continent, and perhaps crossed the Drakensberg Mountains, are dry winds. They blow almost constantly in July, when the subtropical high-pressure belt covers almost all Africa south of Capricorn. This is the dry season, except in the south-west of the Cape Province, which projects to the polar side of the high pressures and lies open to the stormy rains of the westerlies. In January, the southern summer, the high-pressure belt swings south, and is broken by the heated continent over which low-pressure systems form. These cause the winds of South-west Africa to be variable, though easterlies are still predominant.

The cold Benguela current, which washes the whole west coast of the continent as far as the Congo mouth, intensifies the aridity, since any wind from the sea reaches the continent at so low a temperature that the increase of temperature inland soon makes it as drying an agent as the south-east trades.

South-west Africa and the arid part of British Bechuanaland is the counterpart of the Sahara. The region is far less arid than the Sahara, however, owing chiefly to the less width of the southern land mass, and we must avoid the mistaken idea that the Kalahari is a waterless desert. Yet, as Hann points out, the only perennial streams of South-west Africa are the Cunene and the Orange, its northern and southern boundaries, and the watercourse which reaches the sea in Walfish Bay is said to contribute water to the ocean only once in ten years.

We distinguish three regions, the coastal strip, the highlands, and the Kalahari. The coastal strip has west and south-west winds, with hardly a break throughout the year. These are sea-breezes, blowing in to the heated continent, in spite of the general tendency to south-east winds in these latitudes. They naturally blow strongest in summer, and during the afternoon and evening hours. The district is an almost waterless tract, the mean rainfall on the coast itself being probably less than 2 inches a year, falling entirely in summer, except at and south of Lüderitz Bay, where there is winter rain as at Cape Town. Away from the coast the rainfall is heavier, but even at the foot of the highlands, 50 to 100 miles inland, the total is probably only about 4 inches.

Paradoxical though it seems, in a country which is incapable of agricultural development owing to lack of rain, the moist air is one of the greatest discomforts of life. The west wind reaches the land from the cold current charged with fog, which at night is dense enough to wet the ground, so that a certain amount of vegetation lives on it. The mean annual relative humidity at Walfish Bay is 84 per cent. The air is generally raw and cheerless. As the south-west winds make their way inland they become warmer, the fog dissolves, and 70 miles inland it is said to be rare.

Temperature is remarkably low and uniform, and is in striking contrast to that of the east coast of the continent in the same latitude (page 70).

During winter the almost constant south-west wind is occasionally replaced by an east wind, blowing out from the high pressures that form over the land in that season. As the east wind descends from the plateau to the coastal plain, föhn effects are developed, the air is clear, and bright skies replace the usual fog. Remarkably high temperatures and low humidities are experienced. The highest temperatures of the year occur during the winter, under these conditions.

On the highlands, part of the South African plateau, everywhere more than 3,000 feet, and in parts more than 5,000 feet above the sea, the winds are easterly throughout the year, and the sky is remarkably cloudless. The range of temperature both annual and diurnal is great, 109° has been observed by day, followed by frost at night. Frosts are common in winter.

The rainfall is far greater here than on the coast. The southern part receives least, but at Windhoek the yearly total is 15 inches, and at Grootfontein almost 30 inches, and here agriculture is said to be possible without irrigation. In the north the highlands are forested, the annual rainfall being probably 24 to 28 inches. The rain falls in summer, from November to April, almost entirely in thunderstorms. The winter months are rainless.

The rest of South-west Africa is part of the Kalahari Desert, the driest part of the interior of South Africa. It is a low-lying region, the basin of the Molopo River, which river, however, rarely contains running water. The rainfall is least in the south, but even here it is estimated at about 10 inches a year. In the north it is probably as much as 25 inches between Lake Ngami and the Zambesi. The rain falls in summer and is very variable from year to year. The Kalahari resembles other deserts in having a great range of temperature.

CHAPTER XV

NYASALAND AND NORTHERN RHODESIA

The distinction to which attention has been so often drawn between lowland and highland climates in Africa is as important here as elsewhere. Climate records are very few. The lowlands consist of the valleys of the Zambesi and Shiré, and the shores of Lake Nyasa. They have a decidedly tropical and unhealthy climate.

> ‘The heat is frightful just before the rains, the temperature occasionally being as high as 118° in the shade, though at night time falling to 85°, thus rendering it possible to live. In the height of the rainy season the range of the thermometer is not so great, but the heat is often more unbearable owing to its greater uniformity and the moistness of the air. In the months of January, February, and March, the thermometer may be 100° in the day time and only fall to 85° or 90° at night.’
>
> (Sir H. H. Johnston.)

The rainy season is very clearly defined, including the months October to April. There is a slight break in the rains at the end of December, when the sun is farthest south, but they soon return with renewed vigour, and January and February are the wettest months. The annual mean in the Zambesi valley between

Zumbo and the Shiré-Zambesi confluence, and in the lower Shiré valley, is about 35 inches. The amount becomes greater towards the north up the Shiré valley, and on the north-west shore of Lake Nyasa it is probably between 60 and 80 inches. These lowlands are hotbeds of malaria and other tropical diseases. The highlands, which fortunately are of considerable extent, present a great contrast, and here life is not only possible but pleasant for white men.

'Such a place as Zomba (3,000 feet above the sea) may be taken as a fair sample of British Central Africa climate. Here during the cold season from May till September we have a day temperature not exceeding 75° and a night temperature ranging from 40° to 60°. In the months of September, October, and November, the day temperature may rise to 98° and fall at night to 65°. During the height of the rainy season the day temperature ranges from 75° to 95° and the night from 65° to 80°.'

At Blantyre, 3,000 feet above the sea, the mean annual temperature is only 68° ; frost occurs occasionally at night in the dry season. The mean annual range of temperature is about 14°, and the mean daily range varies from about 24° in October to 13° in June. At these altitudes the heat is never oppressive, and if we ascend still higher, we find a climate which is rather too cold for comfort.

The relative humidity is considerable throughout the year, averaging about 75 per cent. The rainy season is November to April as in the lowlands, but above 3,000 feet no month can be called rainless; Fort Anderson (Mlanje) has almost 2 inches of rain even in July and August. The total annual rainfall is far greater than in the valleys. Lauderdale has as much as 107 inches, Zomba has 54 inches, which may be regarded as a typical figure except in the highest and most exposed positions. But Blantyre has only 36 inches ; it is perhaps sheltered by the mountains on the north. The mountains round the north end of Lake Nyasa are exceedingly rainy, with probably more than 100 inches a year (see p. 58).

By far the largest portion of Northern Rhodesia consists of plateau, varying in altitude from over 6,000 feet in the north and east to about 3,500 in the south. The valleys of the Zambesi, Kafue, and Luangwa are much lower. The distinction between highland and lowland climate holds here also, but unfortunately even the highlands of Northern Rhodesia, especially south of Lake Tanganyika, are not altogether free from malaria.

The rainy season is the same as in Nyasaland, about 90 per cent. of the year's rain falling in the months November to April. The mean annual amount is greatest in the north, about 40 inches, owing partly to proximity to the Equator, partly to altitude; in the Zambezi valley between Zumbo and Victoria Falls, it is about 30 inches.

Northern Rhodesia, like the more southern portions of British South Africa, is noted for abundant sunshine.

CHAPTER XVI

PORTUGUESE EAST AFRICA

There are two main types of climate, coastal and interior.

The warm Mozambique current, a continuation of the Equatorial current of the Indian Ocean, extends the length of the coast, giving abundant heat and humidity. The temperature along the whole 1,000 miles is strikingly uniform, the annual mean being 72° at Lourenço Marques, 76° at Beira, and 79° at Mozambique; the latter town is slightly warmer than Mombasa, 800 miles nearer the Equator. The mean annual rainfall is 33 inches at Mozambique, 42 inches at Mopeia, 58 inches at Beira, 27 inches at Lourenço Marques. North of the Zambezi River the rainfall appears to decrease at first from the coast inland to less than 30 inches, but to increase again to over 40 inches in the highlands round Lake Nyasa. Similarly in Gazaland there is a comparatively dry region between the coast and the edge of the plateau. Summer is everywhere the rainy season, especially the period December to May. The humidity of the air is always considerable, and very high during the rains; this in conjunction with the high temperature makes the coast decidedly unhealthy.

The highlands of the interior are, of course, much cooler and are said to be quite healthy, so that even European colonization may be possible, but few details are available.

CHAPTER XVII

MADAGASCAR

Fig. 19 shows that while central and southern Madagascar may be considered as under the influence of the south-east trades always, the north-west of the island has a marked seasonal change, since the north-east trades of the North Indian Ocean extend thus far in January as north-west winds after crossing the Equator. The belt of lowest pressure in January crosses Madagascar in about 15° S. lat. Summer is the rainy season, not because the south-east trades are then strongest, for they blow strongest in winter, but chiefly owing to the influence of the doldrums belt of rising air, into which the winds blow from the east on the east coast, and from the north-west on the north-west coast, their ascent being, of course, hastened by the mountains. The east coast has no dry season, for the ascent of the mountains by the south-east trade wind produces 5 inches of rain even in July. September, October, and November are the driest months, but each has over 3 inches of rain.

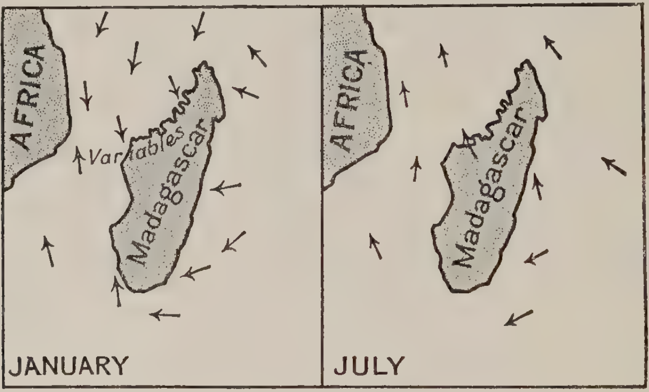


Fig. 19. Prevailing winds.

The east and north-west of the island, both windward slopes in summer, have abundant rainfall, amounting to more than 100 inches per annum in many parts. The south and south-west, on the other hand, which are very low-lying, and partly in lee of the eastern block of high land, are decidedly dry, almost arid, with as little as 16 inches a year in places. In consequence of its clearer skies this region has higher temperatures in summer than the rest of the island, despite its higher latitude.

Much of the interior is over 5,000 feet above the sea, and hence the control of temperature by altitude is important.

Tropical cyclones are frequent in Madagascar, Mozambique, and the off-lying islands, the Comoro group, Bourbon and Mauritius. They are to be expected chiefly in January, February, March, and April; out of 328 storms recorded in Mauritius, 241 occurred in these months, none in August and September.

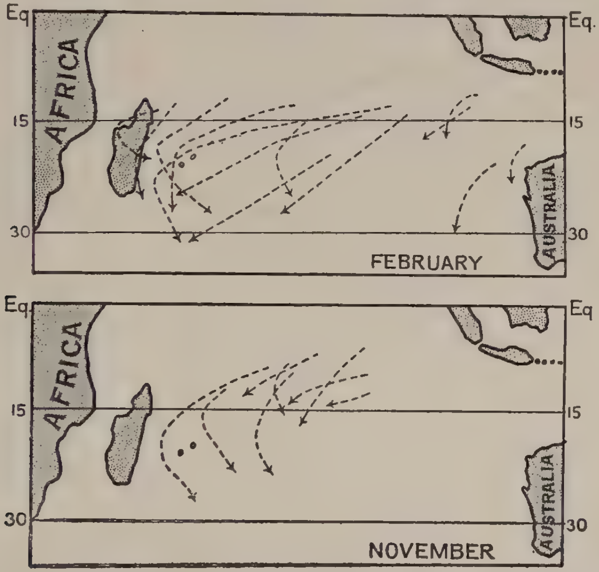


Fig. 20. Typical tracks of tropical cyclones over the South Indian Ocean.

Number of Cyclones recorded in Mauritius in 35 Years

Jan. . .	71	Apr. . .	50	July . .	2	Oct. . .	5
Feb. . .	61	May . .	19	Aug. . .	0	Nov. . .	25
Mar. . .	59	June . .	3	Sept. . .	0	Dec. . .	33
		Total . . .	328				

The cyclones originate over the warm ocean 5° to 15° south of the Equator, long. 60° to 90° E. (the Seychelles are very rarely within their range) and travel first in a south-westerly direction towards Madagascar (Fig. 20). They often follow a parabolic course, and the summit of the parabola shows a tendency to swing north and south with the sun, the cyclones commonly recurving about 22° S. lat. in January and February, and sometimes as far north as 14° S. lat. in May ; as a general rule they recurve between 18° and 22° S. lat. Their track often forms almost a semi-circle round the islands of Bourbon and Mauritius, which are then the scene of dreadful devastation. After recurving the cyclones move away towards the south-east.

CHAPTER XVIII

BRITISH SOUTH AFRICA

(SOUTH OF THE RIVER ZAMBEZI)

Although this area extends through almost 19° of latitude it has so many features of topography and climate in common that it may well be treated as a whole.

During the summer of the southern hemisphere, atmospheric pressure is relatively low, the low pressures having migrated south with the sun from the Equator. There is a fairly steep gradient from the sub-tropical anticyclones of the South Atlantic and South Indian Oceans, and the wind blows in to the continent, from the east, south-east, and north-east in Natal, from south and south-east in the east of Cape Colony, bringing rain and cloud over the whole country.

In winter anticyclonic conditions establish themselves over the land. The air tends to be calm, the weather fine and rainless, and the sky clear. On the east coast, however, south-east winds continue in winter also, this being the prevailing wind direction on the coast as far north as Mozambique throughout the year. Hence South Africa has, speaking generally, rainy summers and rainless winters. But an important exception is the south-west and west coastal district of the Cape Province, which has its rains in winter, and a rainless summer, in other words a ‘ Mediterranean ’ climate.

In summer the sub-tropical high pressures are centred just south of the continent, and partly cover the coastal belt just mentioned, so that the weather is fine and dry. In winter the high-pressure belt has moved north, and Cape Town and its neighbourhood are left on its poleward side, and so are open to the influence of the cyclones of the stormy westerlies. The rainiest district in winter is the extreme south of the province, which lies nearest to the centres of the passing cyclones. It is of interest to note that although winter is the season of cyclones and rain, yet the mean atmospheric pressure is higher then than in summer, being 30·16 inches in July, 29·90 in January, at Cape Town—a good example of the fact that not absolute pressure, but the nature of the pressure distribution in the district, determines the weather conditions.

Altitude has a most important influence on the climate of South Africa, most of which is a plateau of varying elevation. The altitude zones usually distinguished are (i) the coastal plain from sea-level to about 1,000 feet, (ii) the little Karroo, about 1,500 feet, (iii) the great Karroo, 2,000 to 3,000 feet, (iv) the High Veld, about 4,000 to 6,000 feet. This last is the plateau of which so much of South Africa consists, the other three belts being steps or terraces between it and the sea.

The plateau is lowest in the west, along the line joining the Victoria Falls on the Zambezi to the confluence of the Molopo and Orange Rivers. Much of its eastern edge is tilted steeply upwards, to form the Drakensberg Mountains, over 10,000 feet high. The low-lying valleys of the Zambezi and Limpopo carry the coastal climate far inland.

Temperature. The temperature of British South Africa is remarkably uniform, owing to the fact that the highest plateau is in the north, and the general level tends to drop towards the south, so that increase in latitude is counteracted by decrease in elevation. Another factor is that the amount of rain and cloud decreases southward, and hence there is an increase in the duration of sunshine to balance the diminution in the angle of incidence of the sun's rays. This uniformity is well illustrated by the following figures:

			Mean Temperature of			
	Latitude.	*Altitude. Feet.*	*Jan.*	*July.*	*Year.*	*Range.*
Salisbury . .	17° 48′	4,800	69	56	65	13
Bulawayo . .	20° 10′	4,470	71	57	66	14
Pretoria . . .	25° 47′	4,392	72	52	63	20
Bloemfontein . .	29° 8′	4,568	72	48	61	24
Graaf Reinet . .	32° 15′	2,460	73	52	64	21
Cape Town . .	33° 56′	115	69	55	62	14

These plateau stations are typical of most of the area. We note how much cooler they are than stations in similar latitudes in the northern hemisphere. This is not entirely due to their altitude, as is seen if we compare Beira, on the coast of Portuguese East Africa, lat. 20° S., where the mean annual temperature is 75·7°, with Bombay, lat. 19° N., where it is 79·3°. One explanation is found in the small area of the landmass of South Africa, and the vastness of the surrounding seas, as compared with the distribution of land and sea in the same latitudes of the northern hemisphere.

The lowlands are, in general, hotter than the plateau, especially on the east coast, which is washed by the warm Mozambique current; the mean temperatures at Mopeia (Portuguese East Africa) and Salisbury, Komati Poort and Pretoria, near Delagoa Bay (p. 84), illustrate this.

The effect of the cold Benguela current on the west coast, and the warm Mozambique on the east, is evident from the following temperatures in almost the same latitude on the west and east coasts:

MEAN TEMPERATURE °F.

	Feb.	*July.*	*Annual.*
Port Nolloth . .	59	53	57
Durban . .	76	64	70

The low temperature at Cape Town (mean annual 62°) is due to the cold Benguela current. The temperature of the sea surface close to the shore is almost the same for more than 700 miles north of Cape Town, the coldest water being found off the south of South-west Africa. This shows that the cold water is due rather to upwelling along the coast from the deeper strata of the ocean, owing to the pull of the south-east trades which blow over the surface, than to the northward flow of cold water from the Antarctic, though this latter influence cannot be ignored; but if it were the main cause the water would become warmer, however slowly, as it flowed on to warmer latitudes. Warmer water is found not towards the north, but away from the coast, and this corroborates the view that the coldest water reaches the surface along the coast itself from the sea bottom.

As we go round the coast from the Cape of Good Hope towards the east and north, the warm Mozambique current becomes increasingly evident. Thus Port Elizabeth has a mean annual temperature of 64°, East London 65°, and Durban 71°. North of this, however, the change, as we reach lower latitudes, becomes small; Lourenço Marques has 72°, Beira 76°.

In summer (Fig. 28), owing to the clear skies, the plateau enjoys remarkably high temperatures by day, and even the mean monthly temperature is almost as high at Kimberley, 4,042 feet above the sea, as at Durban on the coast, where there is much cloud and the air is moist (Fig. 21). But in winter the plateau is far cooler, Kimberley having a mean July temperature of 51°, while Durban has 65°; this is the result of the rapid loss of heat by radiation through the clear plateau air. Another striking fact illustrated by Fig. 21 is that spring is decidedly warmer than autumn on the plateau. On and near the coast autumn is much warmer than spring, an ordinary marine characteristic. The mean temperature at Kimberley in April is 64°, in October 68°. Thus the temperature curve lags less behind the sun than is usually the case, and this is doubtless due, partly to the clear skies and dry air of the plateau, which enable the ground to heat and cool rapidly, and partly to the fact that the summer rains continue into autumn but have not started in spring, so that April is a cloudier month than October.

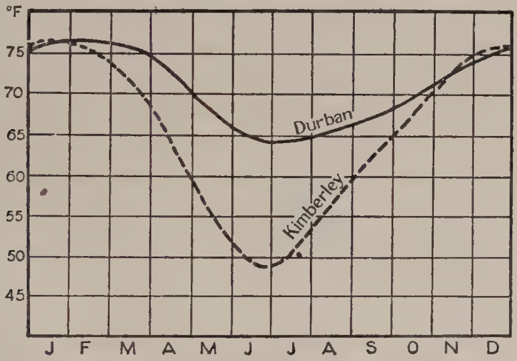


Fig. 21. Mean temperature at Durban (east coast) and Kimberley (interior plateau, altitude 4,042 feet).

The range of temperature is far greater inland than on the coast (see table on p. 69). But in Rhodesia, even so far from the sea as at Salisbury and Bulawayo, the mean annual range is small, owing to the low latitude; it is much greater towards the south, reaching its maximum in the Great Karroo and the south of the Orange River Colony. The daily temperature range also is greatest on the high plateaux, the land heating rapidly under the unclouded sun, and radiating its heat equally rapidly through the clear air at night. The mean daily range is generally about 27° on the high Veld. At Pretoria it is 29° (23° in February, 34° in August). The range is greatest during the dry months when the sky is clearest, that is to say in July and August over most of the region, but in January and February in the south-west of Cape Colony. Very high temperatures are sometimes recorded in the interior, and what is more important for the farmer, also very low ones. The thermometer may fall considerably below freezing point at night in any month of the year on the southern part of the plateau, and in winter ‘ severe frosts, capable of freezing standing water, are practically unknown along the coast but are of fairly frequent occurrence in the interior. As a matter of fact frost is liable to occur at inland stations during any month of the year, but more particularly from May till mid-September, although killing frosts are apt to occur as early as March and as late as October ’. Even the Rhodesian plateau is not immune. The lowest temperature on record is 6°, at Palmietfontein in the north-east of the Cape Province, 4,500 feet above the sea.

Föhn winds, known as Berg winds, descending from the plateau to the coast, are an interesting phenomenon. They have already been described as occurring in South-west Africa. They blow from the east at Port Nolloth, from the north on the south coast of Cape Colony, from the north-west in Natal. They are most frequent in the winter half year, and cause some of the highest temperatures recorded, 110° and more.

Rainfall. The main features of the rainfall distribution are easily understood. The rainfall of the whole region, except the south-west of the Cape Province, probably originates in the evaporation from the South Indian Ocean and is carried into the continent by the SE., E., and NE. winds. Most rain falls during the summer months, when the monsoonal effect is strongest, and the heat of the land causes convectional overturning. The tropical cyclones of the South Indian Ocean sometimes extend their influence over Rhodesia and help to cause the late summer rain of that territory. After crossing the narrow coastal plain the east winds have to rise to the plateau. All this eastern belt receives abundant rainfall, amounting to over 45 inches a year in the highest parts of the Drakensberg, and over 40 inches along the coastal strip, some 40 miles wide, south-west from Durban, where the sea winds are first compelled to give up moisture. The interior of Natal between these two areas of greatest rainfall receives about 30 inches of rain a year.

Beyond the crest of the Drakensberg the land slopes steadily to the west and the rainfall becomes less, as is shown by the following records from stations lying on or near the 29th parallel:

MEAN ANNUAL RAINFALL

	Altitude. *Feet.*	*Inches.*
Durban	260	40
Pietermaritzburg	2,218	29
Drakensberg	10,000	45 (approx.)
Bloemfontein	4,568	22
Kimberley	4,012	18
Uppington	2,800	11
Pella	1,800	3
Port Nolloth	40	2

Any latitude south of the Zambezi, except in the extreme south of the Cape Province, would give a very similar series of records.

The 20-inch annual isohyet follows pretty closely the western boundary of Southern Rhodesia, the Transvaal and Orange River Colony, all the country east of the line having over 20 inches of rain. Bechuanaland has between 10 and 20 inches, except the south-west district which, with the north-west and centre of the Cape Province, has less than 10 inches.

Not only is the rainfall heavier on the east coast, but it begins earlier in the season and goes on later than in the interior. Durban has rain in every month of the year, the real rainy season lasting 9 months, from August to April (Fig. 22). In most of that part of the interior where the annual rainfall exceeds 25 inches the rains begin in October and last till March, a period of 6 months; April is a transition month, and the dry season definitely starts in May. But in the drier region which receives 20 inches or less a year the rains are delayed, and start only in November, and in many parts, in December, a delay which is a great disadvantage for agriculture. The difference in the total yearly rainfall of two stations, which are situated east and west of one another, is largely accounted for by the poor spring rains at the drier western station. We may illustrate this from Johannesburg and Vryburg:

MEAN SEASONAL RAINFALL (Inches)

	Winter. *June–Aug.*	*Spring.* *Sept.–Nov.*	*Summer.* *Dec.–Feb.*	*Autumn.* *Mar.–May.*	*Year.*
Johannesburg .	0·5	7·4	14·7	5·8	28·4
Vryburg . .	0·8	2·1	13·1	6·4	22·4

However in Southern Rhodesia the spring rain is much the same everywhere (except that the elevated eastern escarpments receive more than the rest of the country), and the difference in the mean annual totals is due chiefly to the richer rains received in late summer and autumn in the east:

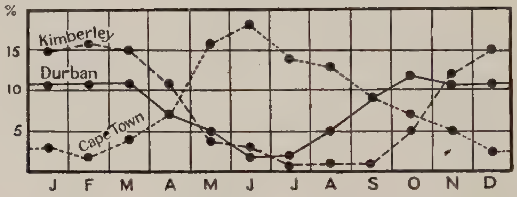


FIG. 22. Mean monthly rainfall (percentage of annual total).

	Winter. *June-Aug.*	*Spring.* *Sept.–Nov.*	*Summer.* *Dec.–Feb.*	*Autumn.* *Mar.–May.*	*Year.*
Salisbury	0·1	5·6	21·6	6·0	33·4
Bulawayo .	0·2	5·6	14·2	3·9	23·8

The spring rains fall almost entirely in local thunderstorms of convectional origin, which are equally frequent both in the east and in the west, and therefore the total spring rainfall is fairly uniform in amount. But the summer rainfall is brought by the general monsoonal inflow from the Indian Ocean, which sets in about December, and the amount is naturally greater on the east side of the continent. Much of the autumn rain is caused by the tropical cyclones of the South Indian Ocean, and their influence also is, of course, strongest in the east. They are probably not felt far inland.

At many stations in Southern Rhodesia there is a slight break in the rains in the middle of December. This is not noticeable in the monthly totals, but appears clearly in the means for 10-day periods (Fig. 23). It coincides with the retreat of the sun to the tropic of Capricorn, the rainiest periods being about the time when the sun is overhead, just as in the southern Sudan the rainfall diminishes when the sun is over the tropic of Cancer. The rain-bearing winds in Rhodesia are shown in Fig. 24.

Southern Rhodesia receives 95 per cent. of its annual rainfall during the summer half-year, Pretoria 90 per cent., Durban 70 per cent. The line separating the summer- from the winter-rain region runs west from the coast between East London and Port Elizabeth, through the Little Karroo and thence NNW. to the coast of South-west Africa between Angra Pequena and Walfish Bay (Fig. 25). Cape Town receives 77 per cent. of its mean annual rainfall in the winter half-year (Fig. 22). Port Elizabeth is typical of the transition region in having both winter and summer rain, 59 per cent. in winter, 41 per cent. in summer (Fig. 26). The winter rain of this south-west coastal belt is brought largely by north-west winds, blowing into the passing depressions in the 'Roaring Forties.'

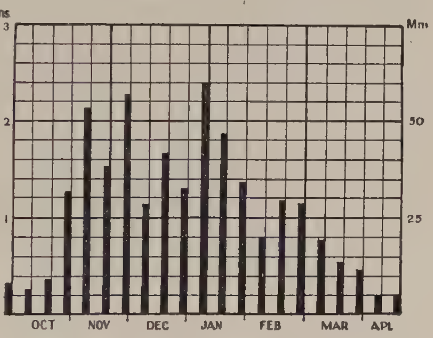


Fig. 23. Mean rainfall for 10-day periods at Bulawayo.[1]

The thunderstorms of South Africa are very violent and destructive. Groups of cattle are sometimes killed by a single flash of lightning, and patches of grass fired. Hailstones of great size often fall at such times, and do much damage to fruit. A large part of the rain falls during thunderstorms, and much of it is lost to agriculture owing to the rapid run-off.

Another most serious disadvantage to the agriculturist is the uncertainty which unfortunately characterizes the rainfall of the whole plateau. Bloemfontein has had as little as 15 inches and as much as 34·5 inches in a year, the annual mean being 25·6 inches. In November 1891, 7·5 inches fell; in November 1877, none at all.

In winter the air is very dry and clear, and the sky generally cloudless. At Johannesburg, in the months June to September, the mean cloud covering is less than two-tenths of the sky; even in February, the cloudiest month, the mean is only five-tenths. The Union of South Africa is justly famous for its remarkably sunny skies. This is perhaps the most striking feature of the climate to a visitor from North-west Europe. An important result of the absence of cloud is the great range of temperature on the plateau. Owing to the scanty rainfall and dry atmosphere the wind often raises clouds of dust, and this is considered to be the greatest disadvantage in the plateau climate from the physiological point of view, especially for persons suffering from lung troubles, who find the dry climate very suitable in other respects. Except for this, it is decidedly healthy on the terraces. The only malarious districts are the coastal plain and the hot low river valleys of the Zambezi and the Limpopo, which carry the unhealthy conditions far inland. The coast of Natal is, however, healthier than the coast farther north.

---

[1] Goetz, *The Rainfall of Rhodesia.* Proc. Rhodesia Sci. Assoc. 1909.

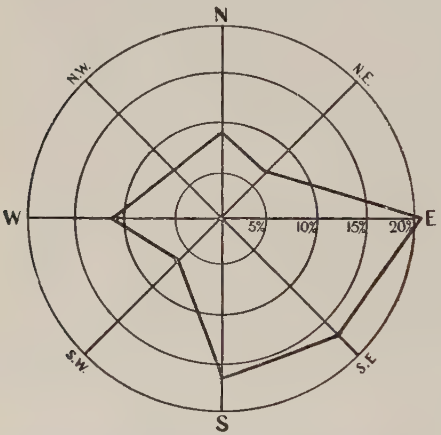


Fig. 24. Rain wind-rose for Bulawayo, showing the percentage of the total Rainfall brought by each wind direction. (Goetz.)

Main Climate Divisions of the Cape Province. The Cape of Good Hope is the most variable province of the Union in respect of climate, and we may divide it into the following nine main regions (Fig. 27). The mean temperature and rainfall at the typical stations may be found on pp. 84 and 88.

Divisions 1 to 4 are coastal.

1. (Typical station, Port Nolloth.) The north-west coast is desert, a continuation of the desert coastal strip of South-west Africa. Its main feature is the very low rainfall, almost everywhere less than 5 inches, and only 2·3 inches at Port Nolloth. Almost all the rain falls in winter. The temperature is remarkably low owing to the cold current which washes the coast, and the

relative humidity is high; fogs are frequent. Away from the coast conditions improve; the air is drier and the sky clearer; the rain is somewhat less scanty and the temperature is higher. The mean temperature for February is 75° at Clanwilliam, some little distance inland, and only 58° at Port Nolloth (Fig. 28).

2 (Cape Town) is at once marked off from 1 by its heavier rainfall, and the 10-inch isohyet may be taken as the boundary between them. We have left the desert and reached a fairly well-watered land. Cape Town receives 25 inches annually, but the rainfall in this neighbourhood is very variable according to locality, even exceeding 200 inches in small areas on mountains near the town. Table Mountain is often capped with dense clouds, especially at the beginning of stormy weather, the phenomenon being known as the 'Tablecloth.' About 70 per cent. of the rain falls in winter. Summer is dry and warm. The climate is of a 'Mediterranean' type, and consequently wheat is successfully grown, and vines flourish owing to the warm autumn. But the temperature, especially in summer, is far lower than at places in the same latitude on the Mediterranean Sea. The mean at Tangier for the warmest month of the year is 76°, at Beirut 81°, but at Cape Town only 70°, since Table Bay contains the cold water of the Benguela current. False Bay, however, only fifteen miles away across the Cape Flats, is often filled by the warm Mozambique current, and is then strikingly

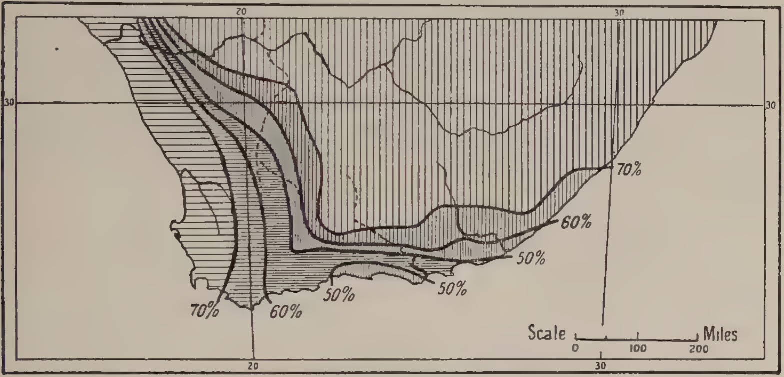


Fig. 25. Proportions of Rainfall in summer (vertical lines) and winter (horizontal lines).

warmer than Table Bay. The sea temperature has been observed to be 67° in False Bay while it was only 51° in Table Bay.

The next division along the south coast, 3 (Port Elizabeth), is chiefly distinguished by having rain both in summer and winter (Fig. 26), the annual total being from 20 to 30 inches. The air is moist throughout the year. Temperature is somewhat higher than in 2, especially in the east, and the range is smaller.

Division 4 (Durban) is a region of well-marked summer rainfall, about 70 per cent. of the annual total being received between October and March. The mean temperature at sea-level ranges from about 65° in winter to 77° in summer. The rainfall is about 30 inches.

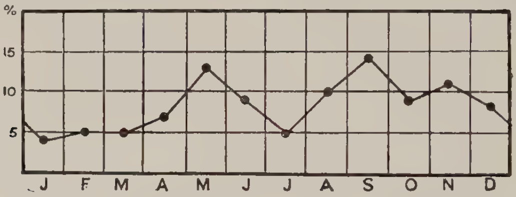


Fig. 26. Mean monthly Rainfall (percentage of yearly total) at Port Elizabeth.

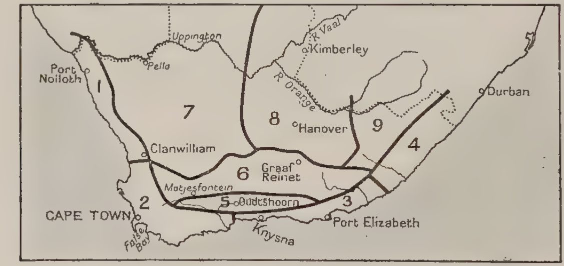

Upington
R. Vaal
Kimberley
Pella
Port Nolloth
1
R. Orange
Durban
7
8
Hanover
9
4
Clanwilliam
6
Graaf Reinet
Matjesfontein
2
5
Oudtshoorn
3
CAPE TOWN
Port Elizabeth
Knysna
False Bay

Fig. 27. The major climate regions of the Cape Province.

The remaining divisions are inland.

The Southern Karroo, 5 (Oudtshoorn), is the first of the terraces rising from the south coast. The average altitude is about 1,500 feet. It is a transition region to the higher plateau.

The Great Karroo, 6 (Graaf Reinet), is the next terrace, 2,500 feet above the sea. The mean temperature in June is about 56°, in January 73°. The mean daily range at Graaf Reinet is 25° in June and 34° in January, the latter figure especially being notably high. In summer a reading of 108° has been recorded; on winter nights frost is usual. The rainfall is very scanty, under 10 inches in the west and centre, in the Ghoup as low as 5 inches. There is no rain except in summer, most of it falling in heavy showers in January, February, and March. The rest of the year is a long dry season when practically desert conditions prevail, and vegetation is burnt up, brown and dusty. The effect of the first rain showers of summer in rousing the plants to life, and carpeting the Karroo with bright flowers, has often been described. The remarkable xerophytic adaptations of the plants bear witness to the scant and uncertain rainfall; sometimes a year may pass without a shower. In the east, however, the Great Karroo has a better rainfall, the annual mean rising to 20 inches.

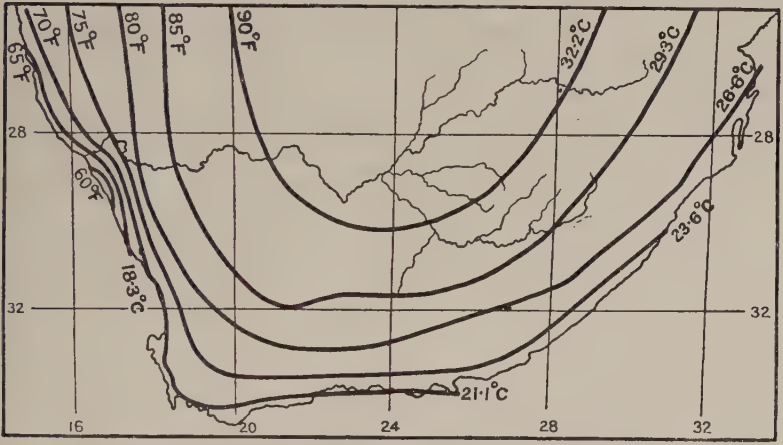


FIG. 28. Mean temperature in January. (Buchan.)

The rest of the Province consists of the High Veld, with an average altitude of about 4,000 feet, but much higher in the east in the Drakensberg Mountains. We divide it into an arid western part, 7, with less than 10 inches of rain annually, far less in the north-west where there is less than 5 inches, a central tract, 8 (Hanover), with a rainfall from 10 to 25 inches, and the more elevated eastern part, 9, with over 40 inches in the highest mountains, and everywhere more than 25 inches. The mean temperature at Hanover, a central town, 4,500 feet above the sea, is 69° in January and February, and 43° in June and July, the mean annual being 57°, 6° less than at Graaf Reinet, 5° less than at Cape Town, the lower latitude being more than counteracted by the greater altitude. We must note, however, that it is chiefly in winter that the plateau temperatures fall below those of the coast; in summer they are remarkably high (see p. 71). The mean daily range at Hanover is 31°, and varies little with the season. The whole of 8 and 9 gets its rain almost entirely in summer; in the north 80 per cent. falls between October and March, and July, August, and September are practically rainless.

MEAN TEMPERATURE (°F.)

MEDITERRANEAN AFRICA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Mogador	33	*57·0*	58·8	60·3	63·1	64·8	67·5	68·2	68·2	**68·5**	66·7	62·6	58·8	63·7	11·5
Morocco	1,542	*51·6*	54·7	59·2	66·7	69·4	77·2	82·0	**85·3**	75·9	69·8	62·4	54·1	67·3	33·7
Algiers	72	*53·4*	55·4	57·6	61·0	65·8	71·4	77·0	**77·5**	74·8	68·5	62·4	55·6	64·9	24·1
Constantine	2,165	*43·1*	45·7	50·4	53·8	62·6	70·9	**79·3**	78·3	72·3	61·2	51·6	44·4	59·5	36·2
Géryville	4,280	*38·8*	42·4	46·2	52·3	60·3	70·2	**78·4**	77·2	68·0	55·9	46·4	40·1	56·3	39·6
Biskra	410	*51·1*	54·9	59·5	66·9	74·7	83·8	**89·4**	88·2	81·5	69·8	59·0	52·2	69·2	38·3
Tunis	141	*49·6*	51·8	54·3	59·5	65·7	74·3	79·3	**79·9**	75·9	67·8	59·4	52·9	64·2	30·3
Tripoli	56	*53·1*	55·9	59·5	64·7	68·9	74·5	78·4	**79·5**	78·1	73·8	65·3	57·2	67·5	26·4
Alexandria	105	*57·5*	59·9	62·7	66·5	71·5	75·7	79·2	**80·5**	78·7	75·3	67·9	61·2	69·7	23·0
Las Palmas (Grand Canary)	30	62·8	*62·8*	63·7	64·9	67·3	70·5	72·1	**73·8**	72·7	71·4	67·5	64·2	67·8	11·0
Funchal (Madeira)	82	59·9	*59·4*	59·9	61·7	63·9	67·1	70·5	**72·1**	71·4	68·5	64·8	61·3	64·9	12·7

THE SAHARA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
El Golea	1,257	*49·1*	53·6	61·5	70·5	77·0	87·6	**93·4**	91·4	84·6	72·1	58·6	49·8	70·7	44·3
In-Salah	1,080	*54·0*	57·0	66·2	76·5	85·3	93·7	**97·7**	95·0	90·0	80·2	67·6	57·2	76·6	43·7

THE SUDAN WEST OF LAKE CHAD, NIGERIA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
COAST															
Gorée	20	68·5	*66·2*	68·2	68·9	71·6	78·3	81·1	81·5	**82·4**	82·0	78·3	72·0	74·8	16·2
Freetown	223	*80·9*	82·0	**82·2**	82·0	81·5	79·5	77·6	*77·4*	78·5	80·2	80·5	**81·4**	80·3	4·8
Cape Coast Castle	Coast	79·9	*79·1*	80·9	**81·2**	80·1	78·0	76·5	*75·5*	76·6	79·0	**80·3**	80·2	78·9	5·7
Lagos	25	*80·2*	81·1	**82·0**	81·5	80·2	77·2	76·1	*75·7*	77·0	78·3	80·4	**80·4**	79·2	6·3
Akassa	20	*78·3*	79·2	79·5	**79·9**	78·8	77·4	76·1	*75·9*	76·1	77·2	78·4	**78·8**	77·9	4·0
INTERIOR															
Bismarckburg	2,329	77·4	**79·3**	78·4	76·5	75·2	72·5	70·2	*70·2*	71·4	73·4	76·5	76·6	74·8	9·1
Misahöhe	1,542	*76·3*	**77·9**	77·7	76·8	76·5	73·9	71·4	*71·1*	72·1	73·9	76·1	**76·5**	75·0	6·8
Wagaduga	2,493	*74·7*	75·6	85·3	**88·5**	86·7	81·1	78·6	*77·7*	79·3	**81·1**	80·6	75·9	80·4	13·8
Kayes	197	*77·2*	80·8	88·7	94·1	**96·4**	90·5	83·7	*81·7*	82·2	**84·5**	83·1	77·2	84·9	19·2
Timbuktu	820	*71·1*	73·6	83·1	91·6	**94·5**	93·7	89·2	*86·5*	**89·2**	88·9	80·8	71·1	84·4	23·4
Kuka	869	*70·7*	74·8	88·9	**92·3**	91·0	89·6	82·9	*79·2*	83·5	**85·1**	79·5	72·7	82·6	21·6

MEAN TEMPERATURE (°F.), *continued*

THE SUDAN EAST OF LAKE CHAD, EGYPT, ABYSSINIA, RED SEA, SOMALILAND

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Port Said	11	*56·1*	57·2	60·4	65·1	70·3	75·4	78·4	**79·5**	77·5	73·9	67·5	59·4	68·4	23·4
Alexandria	105	*56·1*	57·2	60·1	63·7	68·5	73·4	77·0	**78·1**	76·3	73·0	66·4	59·4	67·5	22·0
Cairo (Abbasiya)	98	*52·7*	55·4	60·8	67·6	74·1	79·0	**81·0**	80·6	76·1	71·8	64·0	55·9	68·2	28·3
Asyut	182	*52·9*	55·9	63·0	71·8	78·8	83·8	**84·9**	84·4	79·3	74·3	64·8	56·3	70·9	32·0
Wadi Halfa	421	*57·9*	61·0	68·5	78·1	84·6	88·2	**88·5**	87·4	84·6	79·5	70·0	60·1	75·7	30·6
Atbara	1,163	*68·7*	70·9	77·5	84·4	90·9	**92·8**	90·7	89·6	90·3	86·9	79·3	71·7	82·8	24·1
Khartoum	1,280	*70·3*	73·4	79·2	86·0	90·7	**91·4**	88·5	*86·5*	**88·2**	87·4	80·2	72·1	82·8	21·1
Hillet Doleib	1,283	80·8	82·9	87·1	**88·3**	85·1	81·3	79·9	*79·5*	81·3	**82·0**	81·7	*79·2*	82·4	9·1
Mongalla	1,440	80·4	81·7	**82·6**	81·0	79·0	77·4	75·9	*75·7*	77·2	78·1	79·0	79·2	79·0	6·9
El Obeid	1,866	*67·3*	70·5	75·9	83·1	**85·8**	84·7	80·8	*79·0*	80·1	**81·3**	76·1	68·7	77·7	18·5
Kassala	1,666	*74·3*	76·8	81·7	87·3	**90·3**	87·8	82·8	*81·3*	83·3	**85·8**	83·3	76·3	82·6	16·0
Addis Ababa	8,005	**61·9**	*59·4*	**64·0**	61·2	63·2	59·2	*56·7*	58·9	58·0	60·0	61·4	60·0	60·2	7·3
Port Sudan	18	73·2	*73·0*	74·7	79·2	84·0	88·3	92·1	**92·3**	88·3	83·7	80·4	75·9	82·0	19·3
Berbera	31	*76·1*	76·1	78·1	81·7	87·3	95·7	**97·4**	96·6	91·2	83·3	79·1	77·1	85·0	21·3

KAMERUN

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Duala	39	79·3	**79·9**	79·2	78·8	78·3	76·8	74·7	*74·5*	75·6	75·9	77·9	78·6	77·4	5·4
Yaundé	2,461	73·6	**73·9**	73·6	72·3	72·1	70·9	*70·2*	70·7	**71·1**	*70·7*	72·3	73·0	72·0	3·7

THE CONGO BASIN

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Banana	7	80·4	80·8	**81·5**	80·4	78·6	74·7	*72·5*	72·5	75·9	78·6	79·9	79·9	77·9	9·0
Bolobo	1,083	78·1	78·6	**79·0**	78·4	78·1	77·9	*77·4*	**78·1**	78·1	77·0	*76·8*	77·0	77·9	2·2
New Antwerp	1,230	79·2	**80·1**	79·2	*78·1*	**79·2**	78·4	76·5	*76·3*	77·0	77·4	77·9	78·1	78·1	3·8
Luluaburg	2,034	76·1	*75·7*	76·3	**77·0**	76·6	76·3	76·5	76·3	*75·9*	76·3	76·6	**77·2**	76·5	1·5

KENYA COLONY (BRITISH EAST AFRICA) AND UGANDA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Mombasa	50	79·9	80·3	**81·8**	80·6	78·4	76·5	*75·3*	75·7	77·0	78·4	79·4	79·9	78·5	6·5
Machakos	5,650	64·4	**66·4**	66·2	65·3	63·6	59·9	*58·5*	59·0	62·4	**64·9**	63·3	*62·8*	63·2	7·9
Fort Hall	4,500	64·7	64·8	**67·4**	63·5	62·9	61·4	61·0	*60·2*	64·8	**67·3**	*64·3*	65·0	65·4	7·2
Nairobi	5,450	63·8	64·7	**65·2**	63·9	63·4	61·6	*58·5*	59·3	61·6	**64·8**	64·0	*62·3*	63·2	6·7
Eldama Ravine	7,240	**62·0**	*61·3*	**63·1**	62·9	62·4	61·2	59·5	*58·5*	58·8	58·6	58·9	58·9	60·9	4·6
Kisumu	3,800	**76·9**	76·1	75·4	73·3	73·4	72·5	71·8	*71·7*	73·3	**75·4**	*74·8*	76·2	73·9	5·2
Entebbe	3,863	**72·7**	72·4	71·8	70·2	71·2	70·9	*70·0*	70·5	71·8	72·5	72·2	71·5	71·5	2·7
Wadelai	1,900	80·5	**82·2**	79·3	78·7	77·4	76·5	76·5	*76·0*	77·0	77·7	78·7	79·7	78·2	6·2
Gondokoro	1,500	82·5	84·5	**86·0**	84·0	81 3	79·2	77·8	*77·3*	77·5	78·0	79·0	80·7	80·7	8·7

TANGANYIKA TERRITORY

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Dar-es-Salaam	43	**81·9**	81·7	80·8	78·4	76·6	74·3	73·8	*73·6*	74·7	76·6	79·3	81·1	77·9	8·3
Tabora	3,983	71·6	72·0	71·4	70·9	70·9	*70·0*	70·2	73·2	75·9	**77·7**	75·6	71·6	72·5	7·7
Muanza	3,937	72·1	71·4	72·1	71·8	72·1	*68·4*	71·8	71·2	72·5	70·3	70·9	70·5	71·0	4·1

SOUTH-WEST AFRICA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Swakopmund	20	62·6	63·1	**63·3**	*59·9*	**60·6**	58·5	56·5	*54·9*	56·1	58·1	58·6	61·5	59·4	8·4
Windhoek	5,456	**74·5**	72·0	71·1	68·0	62·4	*56·1*	56·8	60·8	66·0	70·5	73·6	73·8	67·1	18·4

NYASALAND AND NORTHERN RHODESIA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Zomba	3,130	71·8	70·7	69·8	68·5	64·8	61·9	*60·6*	64·0	68·9	74·5	**74·5**	71·8	68·5	13·9
Lauderdale	2,539	*72·8*	**73·6**	72·1	70·2	65·8	*62·1*	62·4	64·9	70·5	74·5	**75·6**	73·2	69·8	13·5
Fort Johnston	1,558	78·6	*77·4*	**77·9**	76·8	73·2	68·9	68·0	70·9	74·8	80·4	**82·0**	79·2	75·7	14·0
Nkata Bay	1,400	77·2	*75·6*	**76·6**	75·0	72·0	67·7	*66·9*	68·6	73·6	77·1	**80·0**	78·0	74·0	13·1
Abercorn	5,100	68·2	65·8	67·2	67·1	65·9	64·4	*63·5*	67·0	69·8	**71·6**	69·7	67·8	67·3	8·1
Livingstone	3,000	75·7	74·5	75·5	72·8	67·7	*63·9*	64·6	67·9	77·2	**80·8**	79·0	77·1	73·1	16·9

MEAN TEMPERATURE (°F.), *continued*

PORTUGUESE EAST AFRICA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Mozambique . .	13	81·9	*81·5*	**82·8**	81·0	77·7	73·9	*73·8*	74·5	77·2	80·1	82·8	83·3	79·2	9·5
Mopcia . . .	32	82·9	82·2	81·3	77·9	73·2	70·0	*70·0*	71·8	76·6	81·7	**84·2**	82·9	77·9	14·2

MADAGASCAR

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Tamatave . .	16	79·3	**80·6**	78·3	76·5	72·5	69·3	*68·4*	69·3	71·2	73·8	76·5	78·6	74·5	12·2
Antananarivo . .	4,593	66·6	**67·1**	66·0	64·2	59·9	55·6	*54·7*	56·1	59·5	63·7	66·0	66·0	62·1	12·4

BRITISH SOUTH AFRICA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Port Nolloth . .	16	59·5	59·9	59·3	57·7	56·8	55·4	55·2	*53·8*	55·0	58·1	59·0	**60·3**	57·6	6·5
Cape Town . .	40	69·3	**69·7**	68·0	63·1	58·9	55·5	*54·8*	55·6	57·0	60·7	64·2	67·3	62·0	14·9
Port Elizabeth . .	181	69·9	**70·3**	68·3	65·1	61·8	59·7	*58·1*	58·8	60·0	62·0	64·7	67·6	63·9	12·2
Port St. John's . .	22	**72·4**	72·3	70·2	69·2	65·0	61·8	*61·1*	61·3	63·7	65·1	67·7	71·1	66·8	11·3
Durban . . .	260	76·6	**76·6**	76·0	72·4	67·8	64·9	*64·6*	66·0	67·6	69·7	72·8	74·8	70·8	12·0
Maritzburg . .	2,225	73·3	**73·4**	71·4	67·8	61·9	*57·6*	58·6	62·4	65·2	67·4	69·1	71·8	66·6	15·8
Graaf Reinet . .	2,500	71·8	**72·3**	68·2	61·8	56·5	53·0	*51·0*	53·8	59·0	63·8	68·5	71·5	62·7	21·3
Hanover . . .	4,500	**69·4**	69·4	64·0	57·3	50·0	42·9	*42·9*	47·7	52·4	58·1	63·3	69·2	57·2	26·5
Kimberley . .	4,042	**75·8**	75·2	72·0	63·6	55·8	*50·2*	50·6	55·5	62·4	68·2	73·2	75·7	64·8	25·6
Pretoria . . .	4,471	**71·7**	70·6	67·8	62·9	56·7	52·6	*51·7*	56·7	63·4	67·6	69·2	71·1	63·5	20·0
Komati Poort . .	—	80·5	79·4	77·0	73·0	68·1	63·1	*62·9*	67·4	72·7	76·0	76·9	**80·6**	73·1	17·7
Bulawayo . .	4,470	71·0	70·0	68·5	65·8	61·4	57·2	*56·6*	61·7	66·3	71·0	71·6	**71·6**	66·0	15·0
Salisbury . . .	4,880	69·0	68·0	67·6	65·4	60·2	56·3	*55·6*	60·4	64·6	69·6	**69·9**	69·2	64·6	14·3

MEAN RAINFALL (inches)

MEDITERRANEAN AFRICA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Mogador	33	2·2	1·5	2·2	0·7	0·6	0·1	*0*	0	0·2	1·3	**2·4**	2·0	13·2
Morocco	1,542	1·3	1·2	**1·4**	1·1	0·7	0·3	0·2	*0*	0·3	0·5	**1·5**	*0·9*	9·4
Algiers	72	4·2	3·5	3·5	2·3	1·3	0·6	*0·1*	0·3	1·1	3·1	4·6	**5·4**	30·0
Constantine	2,165	2·5	2·3	2·7	2·6	1·5	1·2	*0·3*	0·5	1·0	2·2	2·0	**3·4**	22·2
Géryville	4,280	*0·9*	1·2	**2·4**	1·7	2·2	0·7	*0·2*	0·5	1·2	1·5	1·3	**1·5**	15·3
Biskra	410	0·5	0·7	0·8	**1·2**	0·6	0·4	0·2	*0·1*	0·6	0·8	0·4	0·6	6·9
Tunis	141	2·2	*2·0*	**2·4**	1·9	0·9	0·6	*0·3*	0·4	0·9	1·6	2·3	2·5	17·9
Tripoli	56	3·3	1·8	0·9	0·5	0·3	0·1	*0*	0	0·5	1·8	2·4	**4·7**	16·3
Alexandria	105	2·2	0·9	0·5	0·2	0	0	*0*	0	0	0·3	1·4	**2·6**	8·1
Port Said	13	**0·9**	0·4	0·4	0·2	0	0	*0*	0	0	0·1	0·5	0·8	3·2
Las Palmas (Grand Canary)	30	1·4	0·9	1·0	0·7	0·3	0	*0*	0·1	0·2	1·1	**2·8**	2·6	11·1
Funchal (Madeira)	82	4·1	3·3	2·8	2·0	0·9	0·5	*0·1*	0·1	0·7	2·9	**5·1**	4·5	27·0

THE SUDAN WEST OF LAKE CHAD, NIGERIA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
COAST														
Gorée	20	0	*0*	0	0	0	0·9	3·6	**9·9**	5·2	0·7	0·1	0	20·5
Freetown	223	0·6	*0·5*	1·1	5·4	14·8	21·3	36·8	**39·6**	32·5	15·2	5·3	1·3	174·4
Cape Coast Castle	Coast	*0·5*	1·3	2·4	3·5	7·2	**10·2**	2·2	*0·9*	0·9	2·4	**2·8**	0·8	35·1
Lagos	25	1·1	2·0	3·7	6·3	10·1	**19·2**	10·2	*2·4*	5·3	**8·6**	2·4	*0·9*	72·2
Akassa	20	*2·6*	6·5	10·0	8·6	17·0	**18·6**	10·1	*9·3*	19·3	**24·7**	10·6	6·5	143·8
INTERIOR														
Misahöhe	1,542	*0·6*	1·7	3·9	5·4	6·7	**10·5**	7·9	*5·4*	**8·9**	6·2	2·7	1·8	61·7
Bismarckburg	2,329	1·4	1·9	3·3	5·4	6·7	**7·0**	6·1	*4·4*	**10·7**	5·7	*0·8*	1·2	54·6
Wagaduga	2,493	*0*	0	0·1	1·8	2·5	4·5	6·2	**10·6**	5·0	1·3	0	0	32·0
Kayes	197	0	*0*	0	0	0·6	3·9	8·3	**8·3**	5·6	1·9	0·3	0·2	29·1
Timbuktu	820	*0*	0	0·1	0	0·3	0·9	**3·5**	2·8	1·1	0·4	0	0	9·0
Lokoja	230	0·6	0·5	1·5	4·9	6·0	5·5	**7·5**	*6·9*	**10·2**	4·3	0·4	*0·3*	48·6
Bauchi	2,200	*0*	0	0·1	**1·3**	4·1	5·7	10·4	**11·6**	6·3	1·5	0	0	41·0
Kano	1,570	*0*	0	0·1	0·5	3·2	4·8	6·9	**11·3**	5·0	0·4	0	0	32·2

MEAN RAINFALL (inches), *continued*

THE SUDAN EAST OF LAKE CHAD, EGYPT, ABYSSINIA, SOMALILAND

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Port Said	11	**0·9**	0·4	0·4	0·2	0·1	0	*0*	0	0	0·1	0·5	0·7	3·3
Alexandria	105	2·1	0·9	0·5	0·2	0	0	*0*	0	0	0·3	1·3	**2·6**	8·0
Cairo (Abbasiya)	98	**0·4**	0·2	0·2	0·1	0	0	*0*	0	0	0·1	0·1	0·2	1·3
Khartoum	1,280	0	*0*	0	0	0·1	0·3	1·6	**2·2**	0·7	0·2	0	0	5·1
Hillet Doleib	1,283	*0*	0·2	0·2	1·1	3·1	5·4	5·9	**7·1**	4·3	2·8	0·6	0	30·6
Mongalla	1,440	*0·1*	0·7	1·5	4·2	5·4	4·6	5·2	**5·8**	4·9	4·3	1·8	0·3	38·9
El Obeid	1,866	*0*	0	0·1	0	0·4	1·2	3·6	**4·5**	3·4	0·7	0	0	14·0
Kassala	1,666	0	*0*	0	0	0·5	1·3	4·0	**4·4**	2·4	0·5	0	0	13·0
Addis Ababa	8,005	0·6	1·9	2·8	3·4	3·0	5·7	11·0	**12·1**	7·6	0·8	0·6	*0·2*	49·6
Port Sudan	18	0·4	0·2	0·1	0	*0*	0	0·4	0	0	0·3	**1·7**	0·7	3·9
Berbera	31	0·1	0·3	**0·7**	0·5	0·4	0	0·1	0·1	**0**	0·1	*0*	0·1	2·4

KAMERUN

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Yaundé	2,461	*1·6*	2·7	5·9	**9·1**	8·1	4·5	*2·6*	3·3	7·6	**8·9**	5·9	2·0	62·2
Debundja	16	8·0	10·9	17·1	17·3	24·8	59·7	**64·4**	*57·7*	**65·2**	45·2	26·6	15·1	412·2
Libreville	66	8·9	*8·5*	**13·3**	12·8	7·8	0·3	*0·1*	0·7	3·9	14·0	**14·8**	9·7	94·8

CONGO BASIN

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Banana	7	*2·1*	2·3	3·7	**6·1**	1·9	0	*0*	0·1	0·1	1·6	**5·9**	4·7	28·6
Bolobo	1,083	5·0	7·0	*4·6*	**7·2**	5·6	0·4	*0*	2·7	3·8	6·5	9·6	**10·2**	62·6
New Antwerp	1,230	4·1	*3·5*	4·1	5·6	6·2	6·1	6·3	6·3	6·3	**6·6**	*2·6*	**9·3**	66·9
Luluaburg	2,034	7·2	*5·4*	**7·9**	6·1	3·1	0·2	*0·1*	2·5	6·5	6·6	**9·1**	6·6	60·8
Mobaye	1,312	*0·2*	1·7	3·9	5·7	5·1	**9·6**	*4·7*	9·1	**10·5**	8·3	4·8	0·9	64·5
Djole	394	*5·8*	6·6	**10·5**	10·1	6·7	0·8	0	*0*	0·9	9·1	**10·9**	6·5	67·9

KENYA COLONY (BRITISH EAST AFRICA) AND UGANDA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Mombasa	50	*0·8*	0·9	2·3	7·8	**13·7**	3·6	3·5	2·2	*1·9*	3·4	**5·0**	2·2	47·3
Kismayu	66	*0*	0·1	0·2	1·8	**5·5**	3·0	1·9	0·8	0·6	*0·2*	**0·5**	0·3	14·9
Makindu	3,280	*1·1*	1·5	2·4	**4·1**	0·7	0	*0*	0·1	0	0·6	**6·6**	3·7	20·8
Nairobi	5,450	*1·9*	4·2	3·7	**8·3**	5·2	2·0	*0·8*	0·9	0·9	2·0	**5·8**	3·5	39·2
Fort Hall	4,500	*1·2*	2·6	4·5	**13·0**	6·1	1·7	0·9	0·9	*0·8*	4·6	**8·4**	3·6	48·3
Naivasha	6,290	*1·1*	1·4	3·0	**6·4**	2·3	4·0	2·2	2·7	*2·0*	2·2	**3·1**	1·8	32·2
Eldama Ravine	7,240	*1·1*	2·2	3·1	**6·7**	5·0	4·3	3·7	4·7	2·6	*1·9*	**3·1**	1·9	40·3
Entebbe	3,863	*2·6*	3·6	5·8	**9·8**	8·5	5·1	3·0	*3·0*	*3·1*	3·5	**4·9**	**5·1**	58·0
Port Florence	3,756	*3·1*	3·9	4·2	**7·4**	5·3	4·2	*1·6*	2·2	2·8	**3·1**	3·6	**3·7**	45·0
Gondokoro	1,500	*0·1*	0·8	2·0	3·5	**6·5**	*3·9*	**5·0**	4·9	4·4	4·7	1·9	0·4	38·1
Wadelai	1,900	1·1	*0·7*	4·4	3·8	**4·9**	*3·4*	3·9	4·6	4·0	6·6	4·5	0·9	42·8

TANGANYIKA TERRITORY

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Dar-es-Salaam	43	3·7	*2·1*	5·2	**12·3**	8·1	1·1	1·6	*1·1*	1·3	1·3	3·1	**4·4**	45·3
Tabora	3,983	**5·7**	*5·2*	**6·7**	5·2	0·8	0·2	*0*	0	0·3	0·5	3·2	5·7	33·5
Muanza	3,723	*2·5*	3·2	6·5	**8·7**	3·3	1·9	*0·1*	1·5	1·8	3·1	**5·1**	4·9	42·6
Ujiji	2,790	4·6	4·9	**5·3**	5·2	2·5	0·4	*0*	0	0·5	0·6	4·1	4·4	32·5

SOUTH-WEST AFRICA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Swakopmund	20	0	0·1	**0·2**	0	0	0	*0*	0	0	0·1	0	0·2	0·7
Windhoek	5,456	**3·9**	2·7	3·0	1·7	0·2	*0*	0·1	0·1	0	0·4	0·8	1·8	14·8
Grootfontein	5,020	**6·6**	5·0	3·7	1·9	0·2	0·2	0	*0*	0·1	0·6	1·6	4·2	23·9

NYASALAND AND NORTHERN RHODESIA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Zomba	2,948	**11·3**	11·0	8·5	3·8	0·7	0·4	0·3	*0·1*	0·3	1·7	5·4	10·7	54·2
Lauderdale	2,540	18·3	**19·6**	14·0	12·7	5·5	3·8	2·9	*2·0*	3·3	4·0	7·2	15·2	108·5
Fort Johnston	1,590	**8·5**	7·0	4·0	2·9	0·3	0·1	*0*	0·1	0·2	2·1	1·9	6·4	33·5
Nkata Bay	1,400	*8·1*	12·4	**13·2**	11·6	3·3	2·4	2·2	1·1	*0·3*	0·4	0·9	**10·2**	66·1
Kalomo	4,090	**7·6**	7·1	2·2	0·5	0	*0*	0·3	0	1·1	0·4	3·6	7·2	30·1
Leaui	3,300	7·6	**8·2**	4·6	0·9	0·2	0	*0*	0	0·1	0·9	2·8	6·6	32·7

MEAN RAINFALL (inches), *continued*

PORTUGUESE EAST AFRICA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Mozambique	13	7·9	**8·7**	7·4	4·4	2·3	1·0	0·5	1·3	0·5	*0·1*	0·3	4·9	39·3
Mopeia	82	*7·4*	**7·9**	4·9	3·3	0·9	1·0	0·8	0·8	*0·2*	1·1	3·0	**10·8**	42·1

MADAGASCAR

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Tamatave	16	11·2	13·4	**18·6**	13·6	8·8	9·7	10·0	6·5	5·6	4·9	*4·2*	9·0	115·5
Antananarivo	4,593	**12·6**	10·5	7·8	2·3	0·5	0·3	*0·2*	0·4	0·6	2·9	4·5	11·4	54·0

BRITISH SOUTH AFRICA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Port Nolloth	40	*0*	0·1	0·2	0·2	**0·4**	0·3	0·2	0·4	0·2	0	0·2	0·1	2·3
Cape Town	40	0·7	*0·6*	0·9	1·8	3·9	**4·4**	3·5	3·3	2·2	1·6	1·1	0·8	24·8
Knysna	950	2·0	1·8	2·0	*1·8*	2·1	2·7	1·9	2·4	2·9	2·6	**3·4**	2·5	28·1
Port Elizabeth	180	*0·8*	0·9	0·9	1·4	2·6	1·8	1·1	1·9	**2·8**	1·9	2·2	1·6	19·9
Durban	260	4·6	4·5	4·6	3·0	2·0	*0·7*	0·8	2·0	3·7	**4·9**	4·4	4·5	39·7
Maritzburg	2,225	5·1	**6·2**	5·1	2·6	1·1	0·3	*0·1*	0·8	1·8	2·5	5·3	5·0	35·9
Oudtshoorn	1,085	0·5	0·8	0·8	0·6	**1·1**	0·7	*0·3*	0·6	1·0	0·9	1·0	0·3	8·6
Matjesfontein	2,593	0·3	0·7	0·4	0·6	**1·1**	0·5	0·6	0·5	0·4	0·6	0·6	*0·2*	6·5
Graaf Reinet	2,500	1·7	1·4	**2·7**	0·9	1·2	0·4	*0·2*	0·7	1·3	0·9	2·5	*1·4*	15·3
Kimberley	4,042	2·8	**3·0**	2·8	2·0	0·7	0·5	*0·1*	0·3	0·2	0·8	2·1	2·9	18·2
Pretoria	4,471	**5·5**	3·9	3·5	1·1	0·6	0·2	*0·1*	0·2	1·1	1·8	3·7	4·2	25·9
Bulawayo	4,470	**5·9**	3·1	2·8	0·8	0·2	0·1	*0*	0·1	0·3	1·0	4·3	5·1	23·7
Salisbury	4,880	7·5	**8·0**	5·0	0·8	0·2	0	*0*	0	0·5	1·2	3·9	6·0	33·1
Helvetia (Melsetter)	5,000	8·1	**20·8**	6·8	5·4	1·5	*0·8*	0·9	1·1	0·8	2·7	4·3	7·1	60·3
Victoria Falls	2,924	5·3	**6·5**	2·6	0·4	0	0	*0*	0	0·3	1·2	1·6	4·3	22·2

PART III

ASIA (WITH EUROPEAN RUSSIA)

CHAPTER XIX

GENERAL FEATURES

Asia, the largest continent, has an area of seventeen and a quarter million square miles, and from a meteorological point of view the land mass is considerably larger, since Europe and North Africa must be included. It belongs essentially to temperate latitudes; only the southern peninsulas project south of the tropic, and no part reaches the Equator, though Singapore is almost on the line.

The core of the continent consists of vast plateaux, buttressed by great ranges of mountains. Turan and Siberia are low plains, lying north of the central mountains and plateaux, and are thus cut off to a large extent from warm southern influences, since the barrier is high enough to form a more or less impassable wall in the lower strata of the atmosphere. For this reason the winters are exceedingly cold in the northern parts of these plains, the ‘ cold pole ’ of the earth being situated in the north-east of Siberia on the Arctic Circle. This region is much colder in winter than the corresponding part of North America, where the absence of a transverse mountain barrier permits mild winds from the south to moderate the winter cold.

The low temperature of Asia in winter intensifies the sub-tropical high pressures, and causes them to extend far north over the continent, and form a great cushion of heavy air, centred over the Gobi desert (Fig. 31, January). The main current of the westerlies is deflected round the north of the high-pressure system, the centre of which is a region of calms.

In summer the land heats rapidly and not only is the abnormal high-pressure system of winter dissipated, but the normal sub-tropical high pressures are converted to low pressures (Fig. 31, July). The centre of lowest pressure is over Baluchistan and

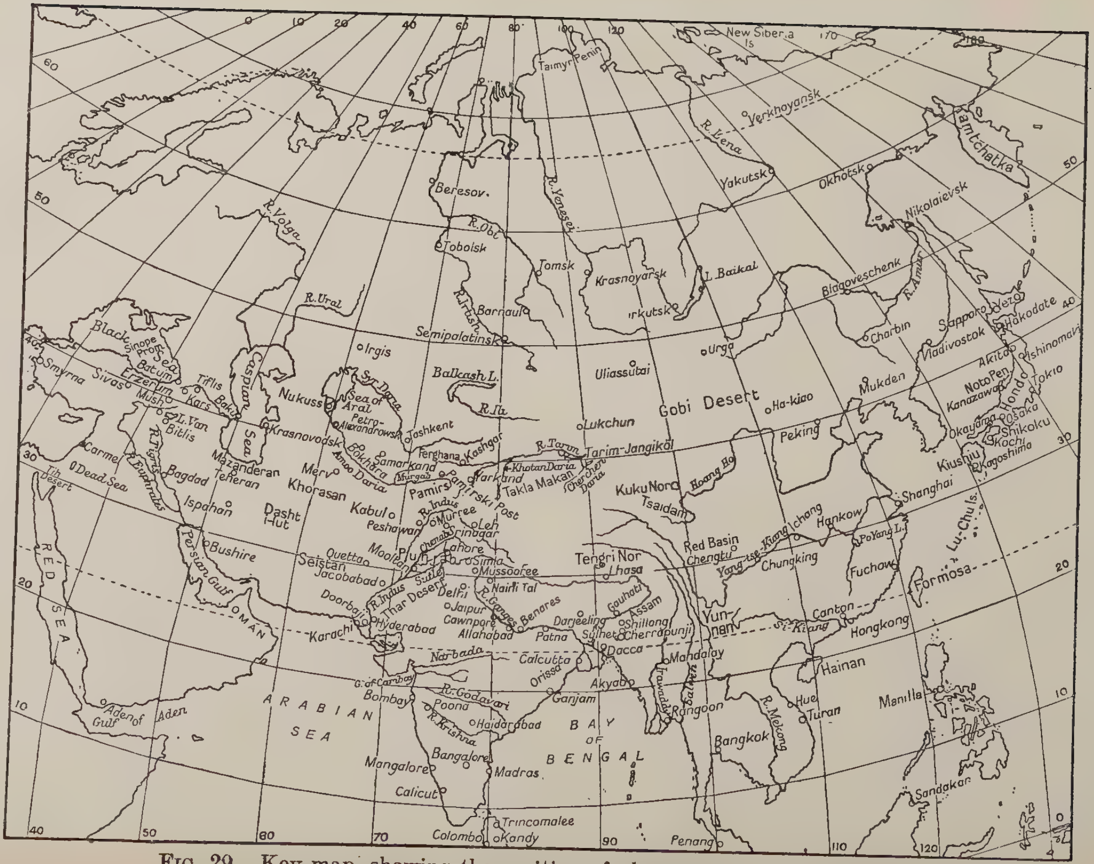

New Siberia Is
Taimyr Penin
Verkhoyansk
R. Lena
Kamtchatka
Yakutsk
Okhotsk
Nikolaievsk
Beresov.
R. Volga
R. Obi
R. Yenesei
Tobolsk
Tomsk
Krasnoyarsk
L. Baikal
Blagoveschenk
R. Amur
R. Ural
R. Irtish
Barnaul
Irkutsk
Semipalatinsk
Irgis
Balkash L.
Uliassutai
Urga
Charbin
Sapporo
Yezo
Hakodate
Vladivostok
Ishinomaki
Akita
Noto Pen.
Tokio
Kanazawa
Hondo
Mukden
Black Sea
Sinope Prom
Batum
Smyrna
Sivas
Erzerum
Tiflis
Kars
Baku
Caspian Sea
Nukuss
Syr Daria
Sea of Aral
Petro-Alexandrowsk
Tashkent
R. Ili
Lukchun
Gobi Desert
Ha-kiao
Peking
Okayama
Osaka
Shikoku
Kochi
Kiushiu
Kagoshima
Mush
L. Van
Bitlis
Krasnovodsk
Ferghana
Kashgar
R. Tarim
Tarim-Jangikol
Carmel
Dead Sea
Tih Desert
R. Tigris
R. Euphrates
Bagdad
Mazanderan
Teheran
Merv
Bokhara
Amoo Daria
Samarkand
Murgab
Khotan Daria
Yarkand
Takla Makan
Cherchen Daria
Kuku Nor
Hoang Ho
Tsaidam
Shanghai
Ispahan
Khorasan
Pamirs
Pamirski Post
Kabul
R. Indus
Murree
Leh
Srinagar
Dasht i-Lut
Peshawar
Red Basin
Chengtu
Yang-tse-Kiang
Ichang
Hankow
Po Yang L.
Lu-Chu Is.
Persian Gulf
Bushire
Quetta
Seistan
Moolian
Punjab
Chenab
Lahore
Simla
Mussooree
Tengri Nor
Lhasa
Chungking
Fuchow
Formosa
Jacobabad
Sutlej
Thar Desert
Nairi Tal
Delhi
R. Ganges
Jaipur
Cawnpore
Benares
Gauhati
Assam
Darjeeling
Shillong
Sylhet
Cherrapunji
Yun-nan
Si-Kiang
Canton
Hongkong
RED SEA
OMAN
Doorbaji
R. Indus
Hyderabad
Karachi
Allahabad
Patna
Dacca
Mandalay
Narbada
Calcutta
Orissa
Hainan
Irawaddy
Salween
G. of Cambay
Bombay
R. Godavari
Ganjam
Akyab
Rangoon
Hue
Turan
Manilla
ARABIAN SEA
Poona
R. Krishna
Haidarabad
BAY OF BENGAL
R. Mekong
Bangkok
Gulf of Aden
Aden
Bangalore
Madras
Mangalore
Calicut
Trincomalee
Kandy
Colombo
Penang
Sandakan
0
10
20
40
60
80
100
120
170
180
60
50
40
30
20
10
0
50
40
30
20
10
40
50
60
70
90
110
120

FIG. 29. Key map, showing the position of places mentioned in the text.

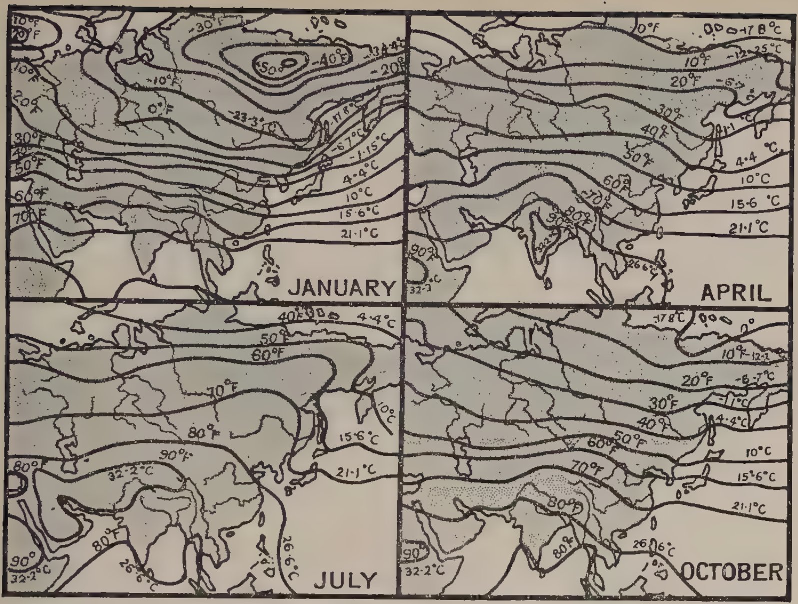

JANUARY
APRIL
JULY
OCTOBER
-30°F
-50°F
-40°F
-34.4°C
-20°F
-10°F
0°F
-23.3°C
-17.8°C
-6.7°C
-1.15°C
4.4°C
10°C
15.6°C
21.1°C
10°F
20°F
30°F
40°F
50°F
60°F
70°F
80°F
90°F
32.2°C
26.6°C
-17.8°C
-12.2°C
-6.7°C
-1.1°C
4.4°C

Fig. 30. Mean Temperature. (Buchan.)

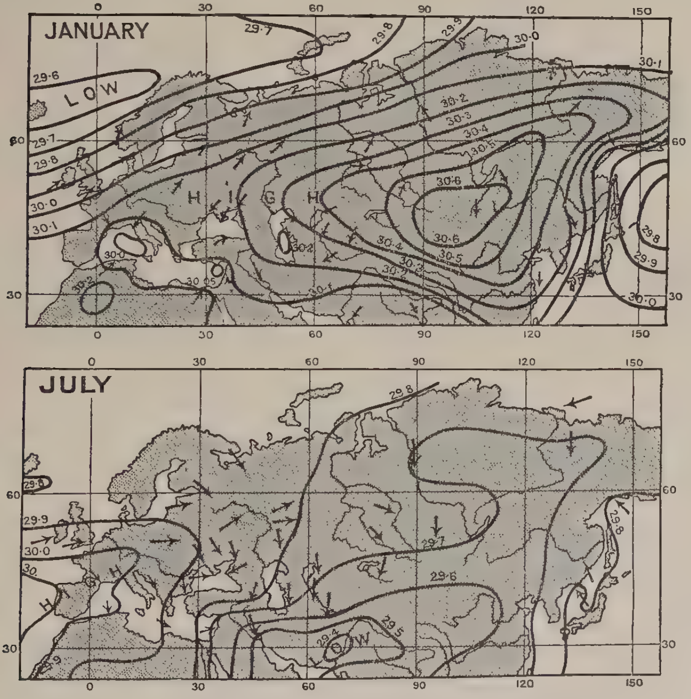

JANUARY
LOW
HIGH
29.6
29.7
29.8
29.9
30.0
30.1
30.2
30.3
30.4
30.5
30.6
JULY
H
LOW
29.4
29.5
29.6
29.7
29.8
29.9
30.0
0
30
60
90
120
150

Fig. 31. Mean Pressure; for India see Figs. 38 and 45.

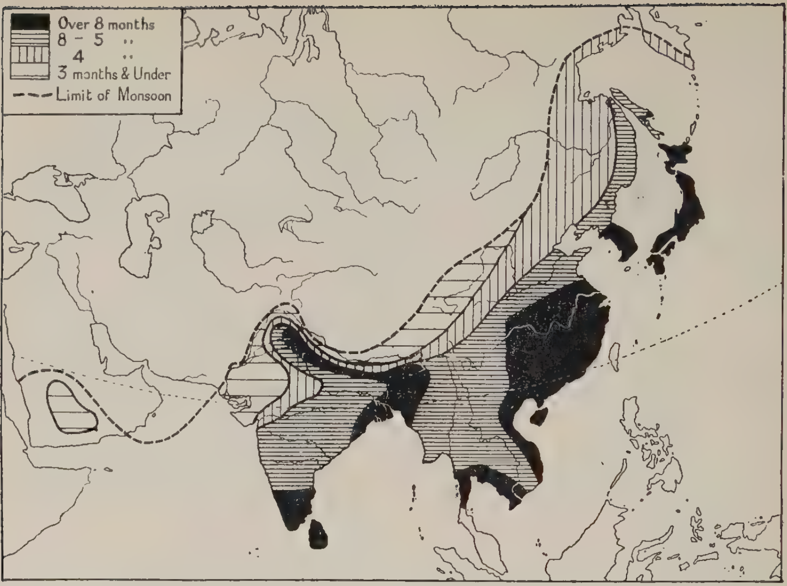

Over 8 months
8 - 5 ..
4 ..
3 months & Under
Limit of Monsoon

Fig. 32. The Duration of the monsoon rains. The extreme south-east of Peninsular India would be more correctly shown as having 8-5 months of rain.

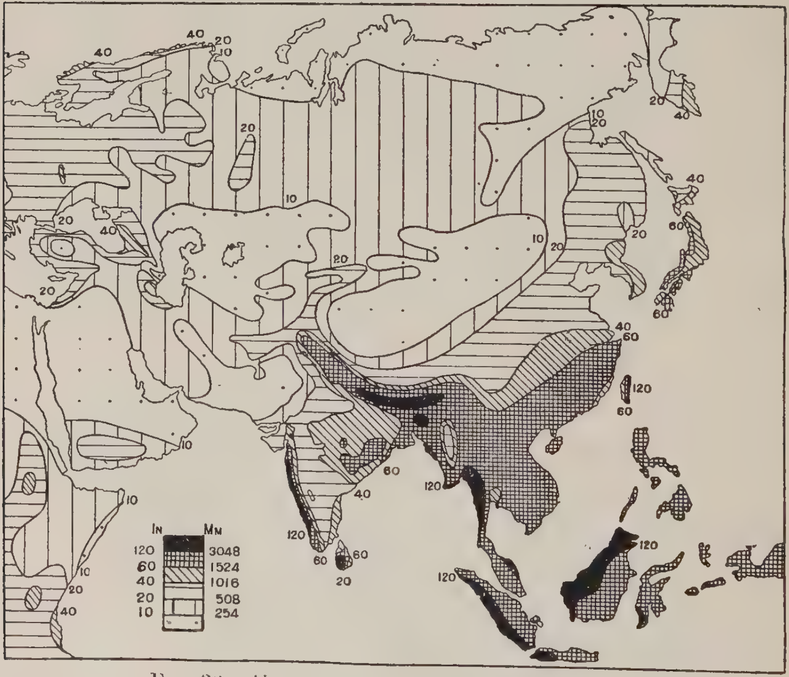

In
Mm
120
3048
60
1524
40
1016
20
508
10
254
40
40
20
10
20
10
20
40
20
40
20
10
20
10
20
20
40
60
60
40
60
120
60
10
10
60
40
120
120
60
60
20
10
20
40
120
120

Fig. 33. Mean annual Rainfall. (Herbertson.)

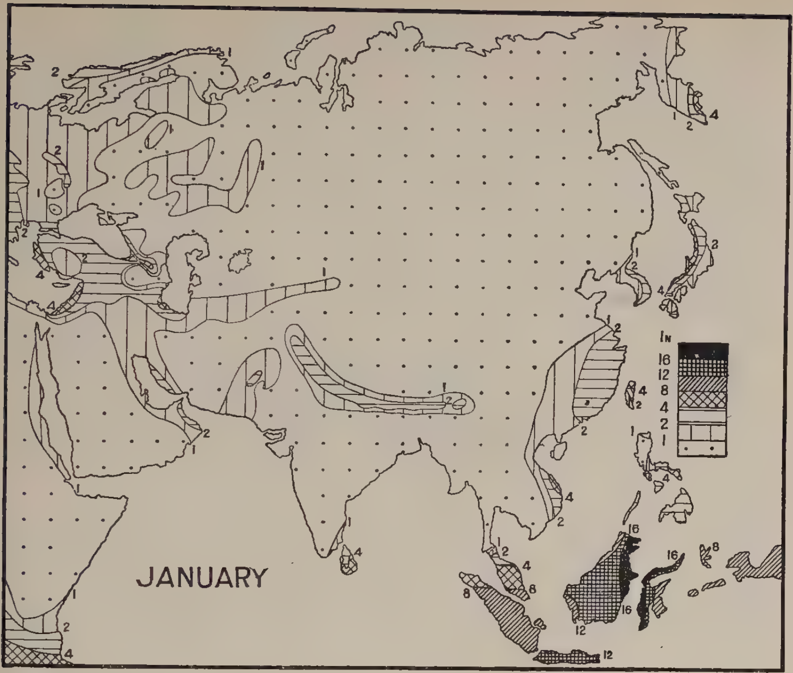

JANUARY
In
16
12
8
4
2
1

FIG. 34. Mean Rainfall in January. (Herbertson.)

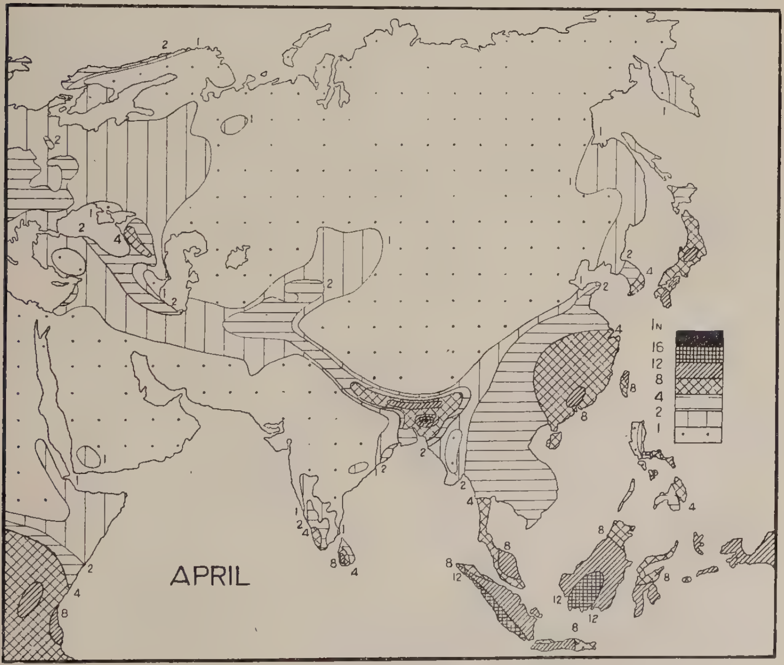

APRIL
In
16
12
8
4
2
1

FIG. 35. Mean Rainfall in April. (Herbertson.)

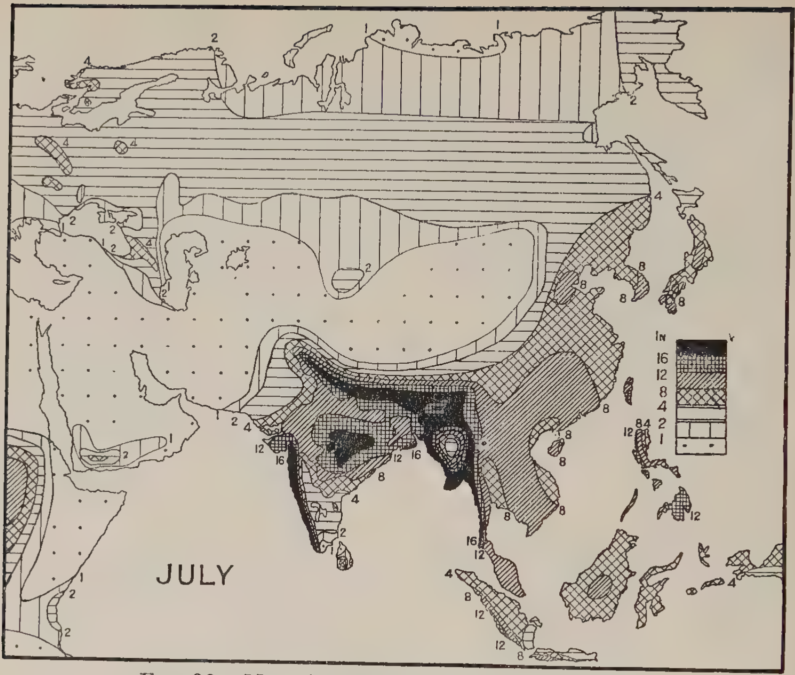

JULY
IN
16
12
8
4
2
1

Fig. 36. Mean Rainfall in July. (Herbertson.)

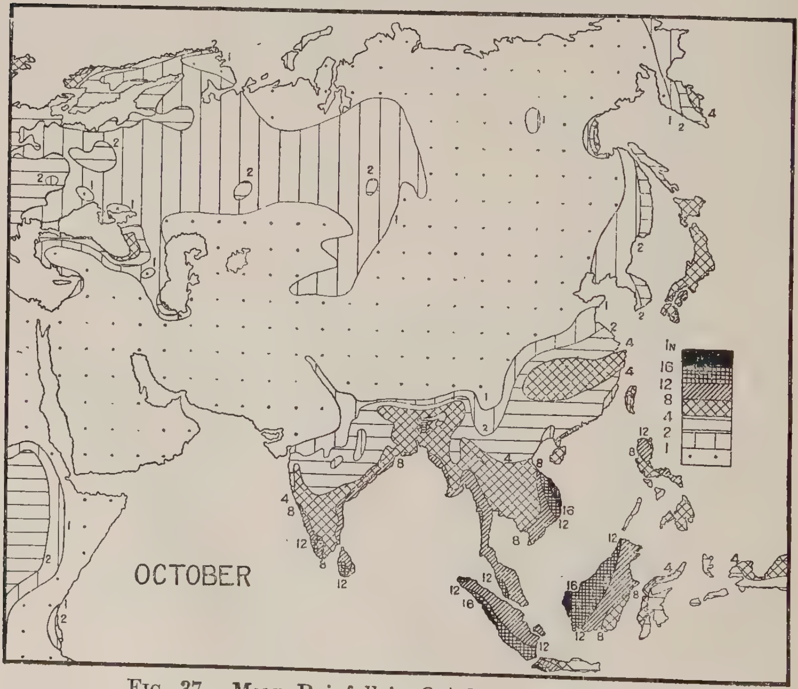

OCTOBER
IN
16
12
8
4
2
1

Fig. 37. Mean Rainfall in October. (Herbertson.)

Sind, and a vast 'secondary' extends north-eastward and covers the whole interior of the continent. The pressure change from winter to summer is the greatest found on the globe, and the resulting seasonal change of wind is remarkably complete. The climate of southern and eastern Asia is often taken as typical of the monsoonal régime, but this is somewhat misleading, since the conditions here are really unique. North America is the only comparable continent, and there the monsoonal reversal of pressure, wind and weather is much less complete, owing, for the most part, to the nature of the relief, and partly to the smaller area of America.

Climatically perhaps the most striking phenomenon in Asia is the rainy summer monsoon. Fig. 32 shows the limits of the monsoon rains, and their duration. In general, summer is the rainy season, and winter is almost or quite rainless (see Rainfall maps, Figs. 33 to 37). It will be our endeavour in the chapters which follow to point out the main differences in the meteorology and climate of the monsoon countries. We shall study the contrasts between the tropical and the extra-tropical monsoons, and note that while the winter monsoon is the dry season in most parts, yet it brings much rain to certain regions, the west coast of Japan, part of China, the coast of Annam, the Malay Peninsula, and the east of Ceylon. We shall see that while in India as a whole the distinction between the rainy summer and dry winter monsoon holds good, yet in every month of the year some part of that country is receiving rain which is important economically.

CHAPTER XX

INDIA, CEYLON, AND BURMA

(This chapter is largely based on the *Climatological Atlas of India*, published by the Government of India, which should be consulted by the reader.)

A country so vast in size and diverse in surface as India must needs have great variety of climate. But a certain unity results from the monsoonal changes which are common to the whole, and we shall base our description on the seasonal rhythm, and follow out the main features of the climates of India month by month.

The year is popularly divided into three seasons, the cold season lasting from October to March, the hot season from March to June, and the rains from June to October, but for our purpose we shall follow the Government Meteorological Department of India, and divide it into

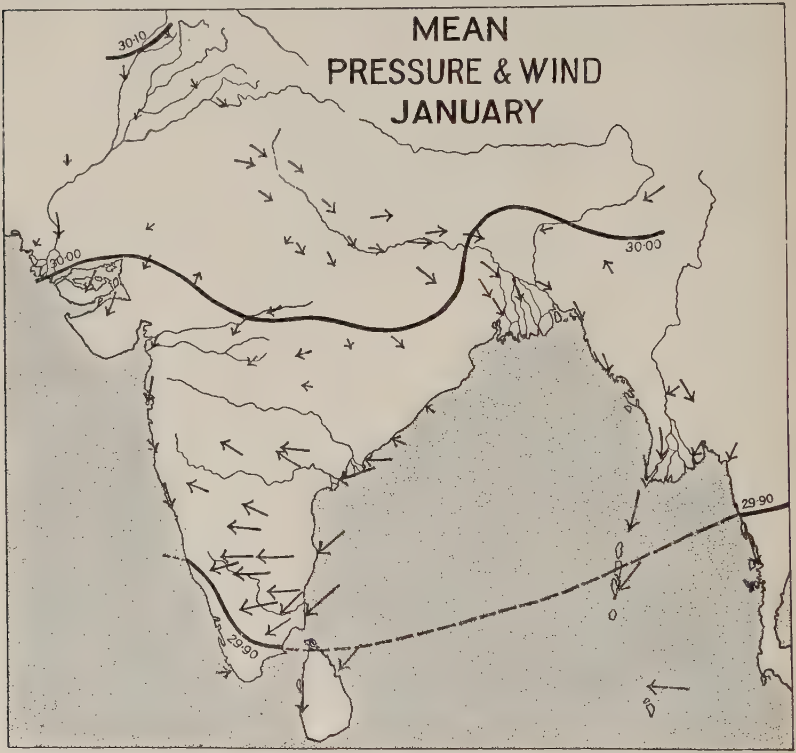


Fig. 38. The constancy of the winds is indicated by the length of the arrows (*Climatological Atlas of India*).

- (*a*) the season of the north-east monsoon.
  - (i) January and February, cold weather season.
  - (ii) March to mid-June, hot weather season.
- (*b*) the season of the south-west monsoon.
  - (i) Mid-June to mid-September, season of general rains.
  - (ii) Mid-September to December, season of retreating monsoon.

Cold Weather Season. January is the typical cold weather month. Central Asia is the seat of very high atmospheric pressure, and over India there is a slight but continuous southward gradient, giving north-west, north, and north-east winds (Fig. 38). It would seem at first sight that the pressure distribution and winds are a direct continuation of those of Central Asia, but this is an erroneous view. The isobars shown on our maps are 'reduced to sea level'. In reality between India and Central Asia the lofty ranges of the Himalayas and the wide plateau of Tibet project high above the lower atmosphere. There are practically no regular observations of pressure from Tibet, but on theoretical grounds it is probable that the pressure at that altitude is very different, not only in intensity, which is obvious, but also in distribution, from that at sea level. The gradient in the middle and upper atmosphere to which Tibet belongs is directed towards Central Asia; the winds blow inwards towards the heart of the continent and owing to rotational deflection appear as westerlies, which are known by observation to prevail in Tibet in winter. They must be part of the upper circulation, which maintains the high pressures over Central Asia. These in turn produce outblowing winds in the lower atmosphere, which are the chief feature of the meteorology of East Asia. But India is quite cut off by the mountain barrier from these outflowing winds. The north-west winds of the plains of north India must be regarded as local in origin, that is to say, the downward settling of the air which feeds them must be going on over the north of India itself, and not over the interior of Asia. On reaching the lower layers of the atmosphere the currents become horizontal, with a general movement towards the south. In north India the winds are north-west and west, guided apparently by the great Ganges plain. In the gorges of the Himalayas through which the rivers reach the plains the wind blows downstream to the plains of India often with considerable force by night, but the night winds are balanced by the valley breezes which blow up the valleys during the day, so that these currents are only of local significance. Occasionally, it is true, wind currents have been traced which have crossed the ranges into India from Afghanistan, and even from Russia. But even in the extreme north-west of India we do not find such cold waves as in China and Mesopotamia, which could hardly fail to appear if the Himalayas did not shut off India more or less completely from the cold interior of Asia.

The winds in north India are very light, averaging only 2 or 3 miles an hour; this, as has been pointed out, would seem to explain the fact that windmills are not used by the natives. In Burma the winds are north and in peninsular India and in Ceylon generally east and north-east, but northerly on the west coasts. The air movement is rather more rapid in the south than in the plains of north India, but the wind cannot be described as strong.

The goal of the north-east winds of the winter monsoon is the equatorial trough of low pressures, now situated somewhat south of the Equator over the Indian Ocean. Still farther south over the south Indian Ocean lies the subtropical high-pressure belt of the south hemisphere. The south-east trades blow from it to the doldrums, where they meet the air-currents of the north-east monsoon, and rise with them into the upper regions of the atmosphere.

January is a beautifully fine month in most of India. The off-shore winds give little or no rain. The sky is remarkably cloudless; hardly anywhere does the cloud covering exceed two-tenths and in the west of the Deccan and in Burma it is less than one-tenth. Thus during the cold season India enjoys a climate almost as sunny as is known anywhere on the earth. The cloudiest parts are the north-west and the extreme south, but even here the sky is far clearer than in England.

The clouds of the north-west are due to the cold-weather storms which are an important exception to the generally fine conditions. At intervals during the months December to March cyclones appear, coming from Persia and Afghanistan, and travel slowly eastward over the Punjab and down the plains (Fig. 39). They resemble the cyclones of the westerlies. There are not yet sufficient data to justify a statement as to their exact origin and cause; to dogmatize is as impossible here as in the matter of the cyclones of the westerlies. There seems to be a close connexion between them and the depressions which appear in winter over the Mediterranean Sea, since the winter cyclones of north India occur in the same season in nearly the same latitude, and move in the same direction. Indeed, many depressions have been traced passing from the Mediterranean across Syria and Iran into India. They are only shallow disturbances and are not usually accompanied by strong winds; their influence does not extend into the Deccan. They are very important in that they provide an appreciable rainfall (from ½ to 2 inches in January, i. e. nearly as much as that of an English July), on which the winter crops, wheat, barley, &c., in the north of India depend (Fig. 40). The rain is heaviest on the north-west frontier, and in the Punjab; the Ganges plain benefits occasionally, but the storms have usually died out before they can reach Bengal. The inner ranges of the Himalayas (Srinagar, Fig. 41) and probably all the highest parts of the chain derive the greatest part of their annual snowfall from them. At Peshawar (Fig. 54) and in

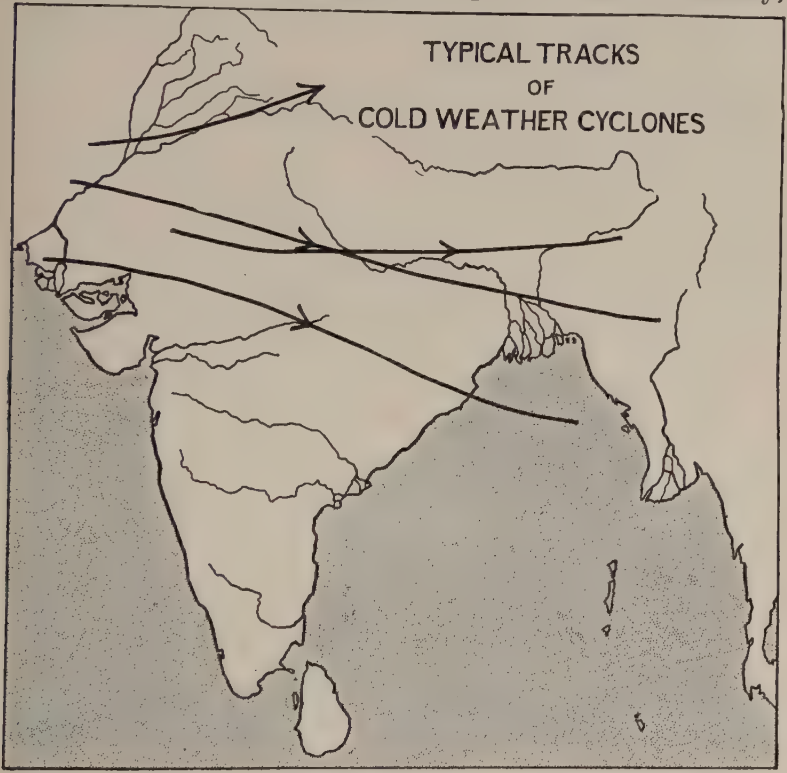


FIG. 39.

Afghanistan also the winter precipitation exceeds the summer. But in the Punjab and farther east the effect on the annual rainfall curve is merely a secondary maximum in the early months of the year, which is far surpassed by the summer maximum (Lahore, Fig. 41). A failure in the winter rains causes considerable distress among the agricultural population all over north-west India.

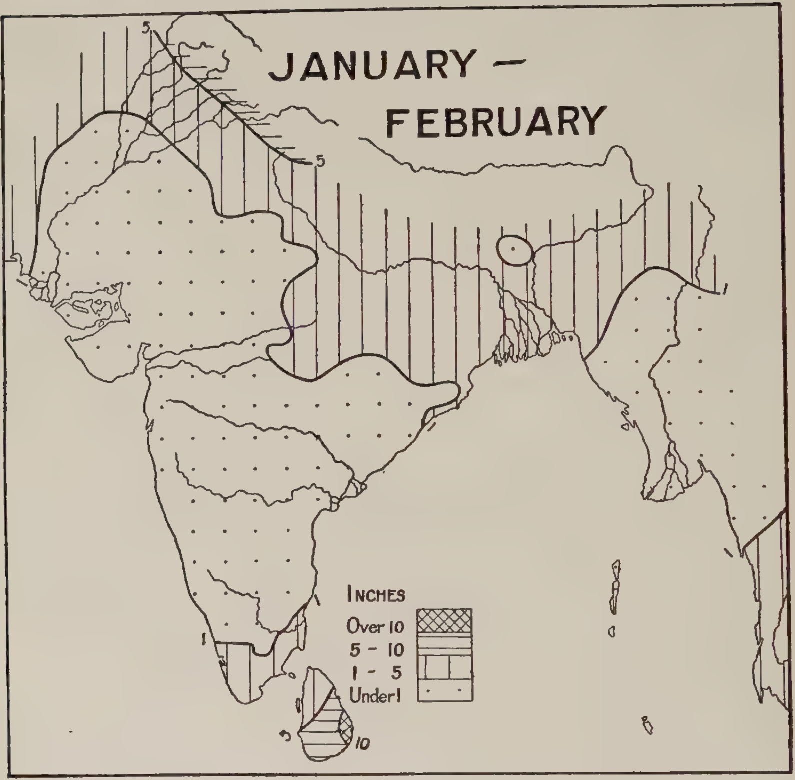


FIG. 40. Mean Rainfall of the cold weather seasons (*Climatological Atlas of India*).

Ceylon and the extreme south of India provide another exception to the fine dry weather of most of India, since they are situated less than 10° from the Equator and are therefore liable to be influenced by temporary northward migrations of the equatorial low pressures. The east and south of Ceylon has heavy rains, brought by the north-east monsoon, which has crossed the warm waters of the south of the Bay of Bengal, and is forced to rise over the central mountains of the island. On the east coast there is a rainfall of over 5 inches in January.

The temperature in India in January (Fig. 42) is comparable with that in Europe in July. On the north-west frontier the mean is below 55°, at Peshawar 50°; in the Indo-Gangetic plains, North and Central Burma, and the north of the Deccan from 55° to 70°, as in North and Central Europe; and in the centre and south of the peninsula, Ceylon, and south Burma, from 70° to 80° as in Spain, Italy, and Greece. In north India Europeans find the conditions very pleasant. 'In his consciousness of awakened energy the expatriated European feels that it also is the cold season, refreshing and invigorating, and affording him a climate than which Italy itself can offer nothing more delightful. The thinly-clad native, inured to heat, and living in a draughty hut, with perhaps a single meal a day of not very stimulating food, is less enraptured with the delights of the cold weather. In the early morning his limbs are benumbed and his faculties torpid, and he swathes his head and mouth in a fold of his body cloth, and cowers over the embers of his little fire, till the warmth of the ascending sun restores him for some hours to his state of normal activity.' (BLANFORD.)

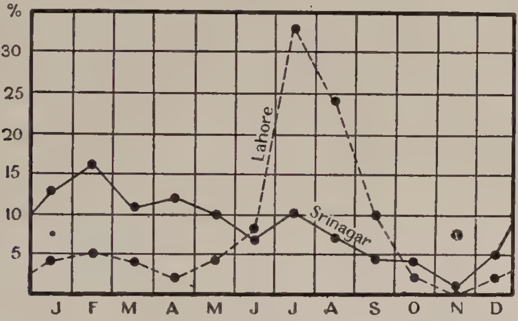


FIG. 41. Mean monthly Rainfall (percentage of yearly total).

The daily range of temperature is far greater than in Europe. The heat of the day in north-west India is not much greater than in England in July, but the nights are considerably colder, and frost is common; Peshawar has recorded temperatures below 25° and enjoys dry and bracing weather. In Rajputana frost is rare, in Bengal and Assam unknown, and the air is much less bracing owing to the abundant moisture; at night fog often lies thick on the low plains. On the coasts of the peninsula and Ceylon the temperature is much more uniform as well as higher than in the north-west. In Ceylon, which is the hottest part at this season, the thermometer rarely falls below 70° or rises above 85°, and, compared with that of the north of India, the air is damp, having a mean relative humidity of 70 per cent. But in the east of the island it is much drier in January than during the rest of the year, and the dryness is considered the disagreeable feature of the January weather.

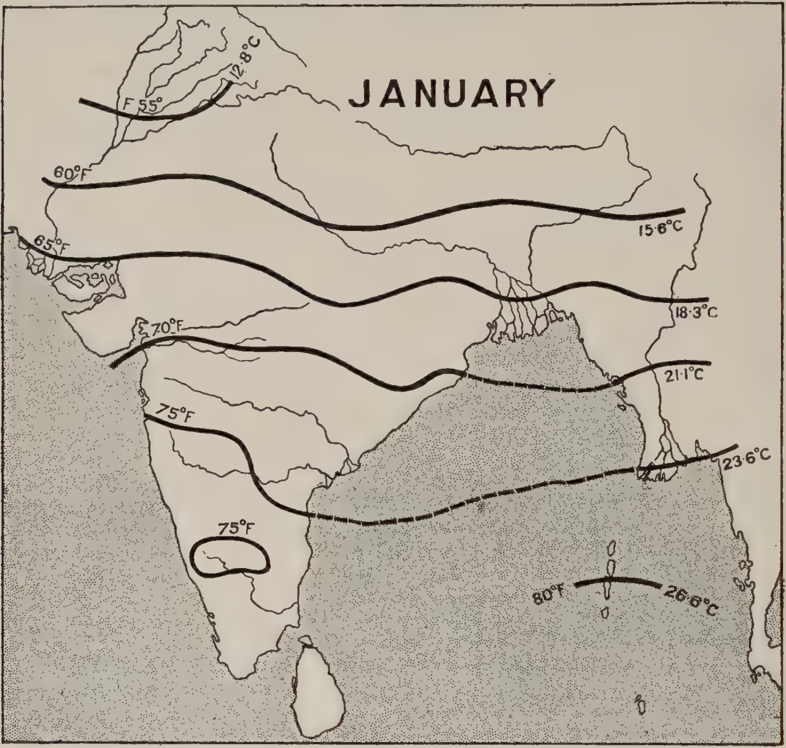


FIG. 42. Mean Temperature (*Climatological Atlas of India*).

In February there is but little change. Pressure and winds remain much the same, except on the west coast of the peninsula where the winds are now westerly and north-westerly. Cyclones continue to appear in the north-west, and in some districts give more rain than in January.

Hot Weather Season. In March the hot weather season begins. With the northward movement of the sun temperature rises rapidly, especially in the interior of the Deccan, and the atmospheric pressure diminishes, becoming somewhat lower over the heated land than over the sea ; the Bay of Bengal is covered by a slightly marked anticyclone. The wind is still north-west over the plains, but on the coasts the sea breezes become more powerful, blowing from the west on the west coast of the peninsula and from the south on the east coast and in Bengal. These sea breezes bring moist air, and a little rain to the south of India and Ceylon, and to Bengal and Assam, but the rest of India is unaffected by them, and the relative humidity of the air is becoming less with the rising temperature.

In April and May the sun is far in the northern hemisphere, and the heat becomes greater and greater (Fig. 43). The north of India is hottest owing to the dry air and cloudless skies. In the plains the mean temperature is above 85° in April and above 95° in May. On an average day in May the thermometer will exceed 105° in the United Provinces, and occasional readings up to 120° must be expected. In Sind the heat is still greater, and Jacobabad, situated near the Thar desert, is one of the hottest stations in India. It is true that the diurnal temperature range is great, over 25°, but even a drop of 30° from such furnace heat at midday leaves the night temperature 75° to 80°, high for a July midday in England. Few parts of the world are hotter. Work must be suspended during the hottest hours, and any activity out-of-doors is impossible as long as the sun is above the horizon. It is dangerous to venture into the open at all without taking careful precautions against sun-stroke, for the heat and the glare, both direct and reflected, are intense. A good description of the weather at this time by a resident is given later (p. 127). The air is very dry indeed ; relative humidities as low as 1 per cent. are sometimes recorded ; all vegetation is burnt up, not a green thing is to be seen. The sky is almost cloudless, but it cannot be described as clear or blue, since there is a constant dust-haze, a grey pall, through which the sun shines as a pale disk. There is no rain at all.

In the south of India the heat is far less. In Ceylon and on the west coast of the peninsula the mean temperature in April and May is between 82° and 85°, and at midday 100° is not likely to be exceeded. But if the days are cooler, the nights are warmer than in the north, the diurnal range of temperature being considerably less. Moreover, the air is moist and there is a considerable rainfall especially in western Ceylon. The south of India and Ceylon have a much warmer climate in the cold season than the plains of north India, but a considerably cooler one in the hot season. Both the annual and the diurnal range of temperature are much less in the south (Fig. 44).

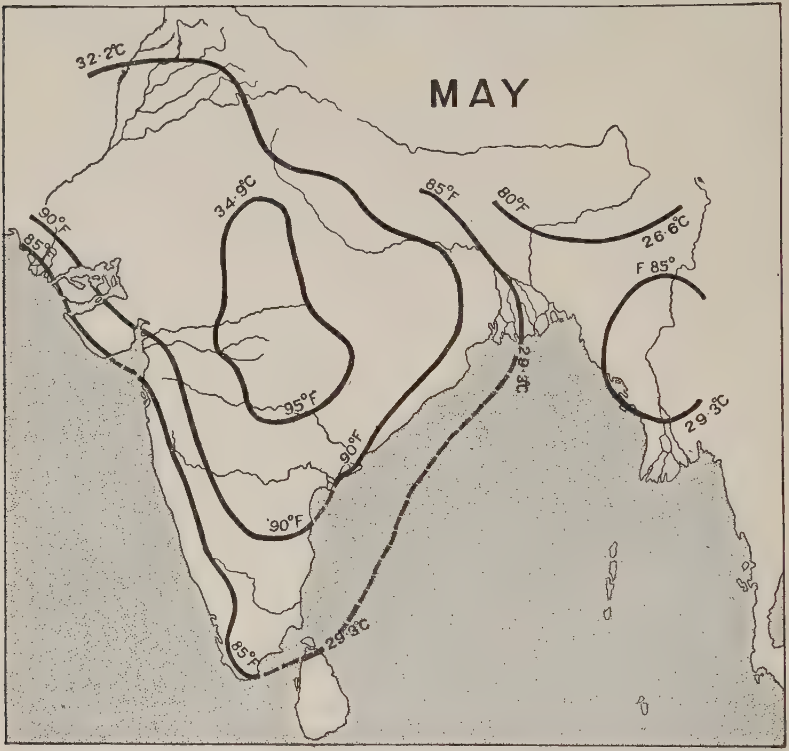


Fig. 43. Mean Temperature (*Climatological Atlas of India*).

While the temperature rises the pressure over India is becoming less and less. By April (Fig. 45) a definite low-pressure system has formed over the land, surrounded by feeble gradients, which become considerably steepened in May; indeed in May the gradient is almost as steep as when the south-west monsoon is at its height. A similar system, possibly deeper, and developed earlier, but instrumental observations to establish this are lacking, forms over the south of Arabia. The wind is on-shore round the coasts of India, bringing considerable humidity. In the south-west of the peninsula and in the centre and west of Ceylon there is a mean rainfall (Fig. 46) of over 5 inches in April, and over 10 inches in May, the 'Mango-showers' of south India. Assam and Burma also have considerable rainfall, but with these exceptions the hot season is one of intense heat and fine, dry, almost rainless, weather. The heat, it is true, has already caused a definite low-pressure system to develop, and there are on-shore winds on the coasts. But the summer monsoon has not yet started; the season may be regarded as one of preparation for its arrival.

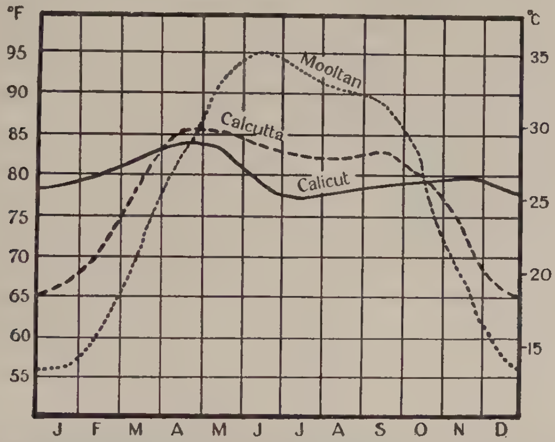


FIG. 44. Mean Temperatures. Compare the range at Calicut (South India, coast) and Mooltan (North India, interior). The fall in temperature with the setting in of the south-west monsoon is clearly marked.

There are certain storms associated with the hot season in the north of India, which must be mentioned. In the dry north-west they take the form of violent squalls of wind of short duration, accompanied by extremely thick dust-clouds, so thick that it is sometimes dark at midday. These squalls occur during the heat of the day, and cause a very welcome cooling of the air, though there is rarely any rain. Similar squalls are known throughout the plains, but nearer the sea the air contains much moisture, owing to the prevailing on-shore winds, and the squalls, known here as ‘ Nor-Westers ’, generally take the form of violent thunderstorms with sharp showers of rain and hail. The April and May rainfall of Bengal, Assam, and Burma is largely of this kind. In Assam the rain is of great importance for the tea-crop.

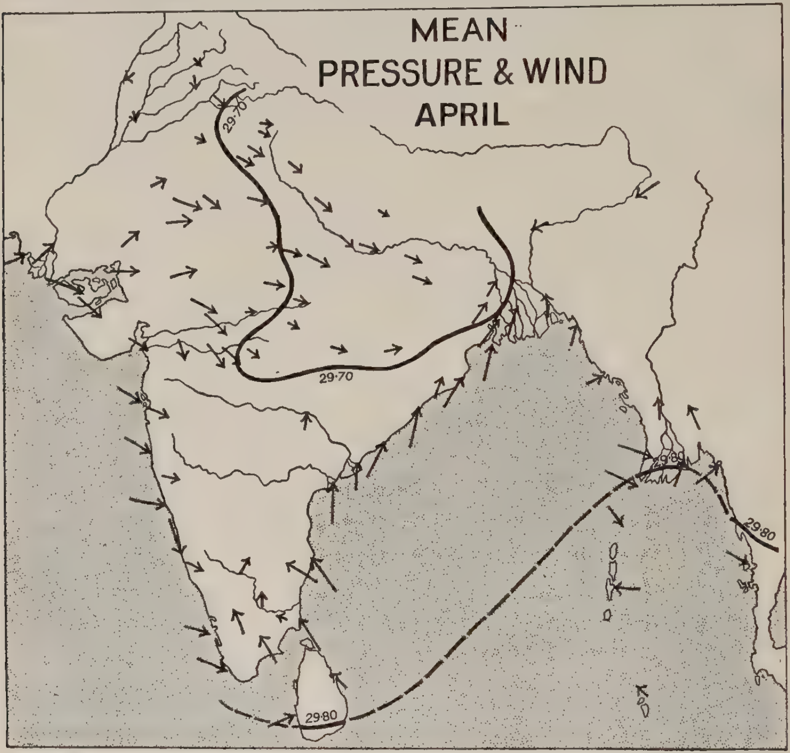


Fig. 45. The constancy of the winds is indicated by the length of the arrows. (*Climatological Atlas of India.*)

The cause of the squalls is doubtless the existence of a dry, cool, north-westerly wind at some little height above the surface of the earth, blowing over the hot and moist winds from the sea ; convectional overturning with much precipitation naturally results. The same regions occasionally suffer from tornadoes, or whirlwinds of small diameter, usually some few hundred yards ; trees and buildings may suffer serious damage, and even heavy objects may be carried considerable distances.

Over the seas round India the mean pressure gradient is slight, and the air currents are weak and variable. These conditions are favourable to the development of tropical cyclones, especially in the south of the Bay of Bengal (see p. 121).

Season of General Rains. In the beginning of June the features of the hot season just described are still more intensified, and the heat and drought become unbearable in the plains. But about the middle of the month, quite suddenly, there is a great change. The south-west monsoon sets in, or to use the ordinary word which well expresses the phenomenon, the monsoon 'bursts'. It is a change not so much in the direction of the wind, as in its force and in the whole face of the weather. The wind blows strongly from the south-west, very strongly over the sea; the sky becomes overcast and the air saturated with moisture. A

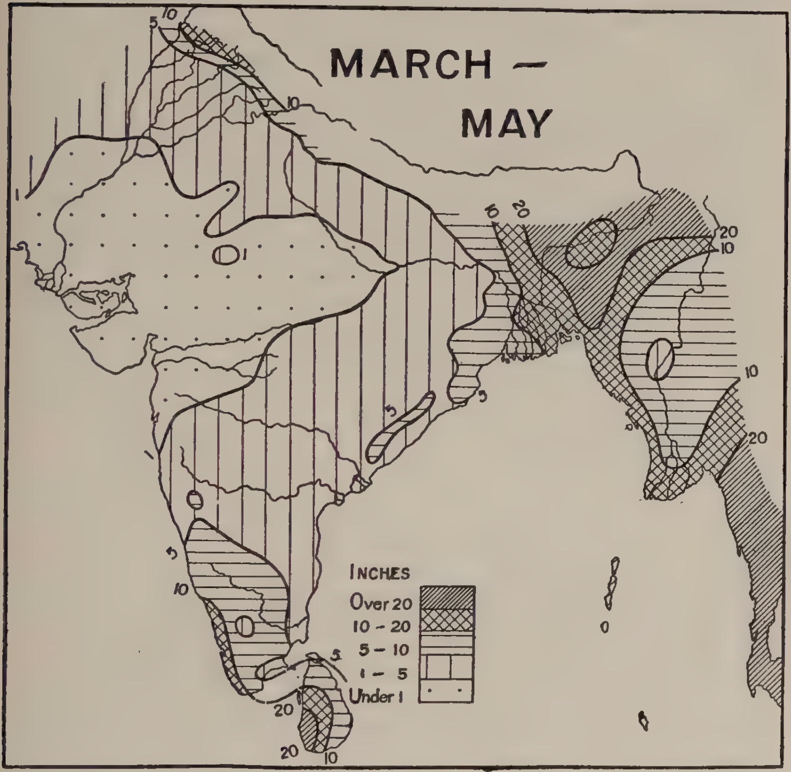


FIG. 46. Mean Rainfall of the hot weather season. (*Climatol. Atlas of India.*)

downpour of rain, with violent thunder and lightning, initiates the rainy and moist conditions that will prevail for the next three months. The clouds shelter the earth from the sun and the streaming rain helps to cool the air ; over most of India the temperature falls decidedly (Figs. 44, 52). Living things feel a sense of relief, and the parched land drinks and becomes luxuriantly green again.

During the hot season pressure diminishes over N. India. As early as the end of May there is a definite centre of low pressure over Sind and Baluchistan, in precisely the same place as at the height of the monsoon. We may lay stress at this point on the exact position of this goal of the in-blowing winds of India ; the south-west monsoon is making for NW. India, not for Central Asia. Round the coasts there are fairly constant sea breezes during the hot season. The south-west monsoon is not merely an intensification of these sea breezes, but over most of India a complete and catastrophic change. The south-east trades of the south Indian Ocean cross the Equator, become south-west winds north of the line, when they come under the influence of the right-handed rotational deflection of the northern hemisphere, and surge on over India. Thus the south-west winds of the monsoon are very different from the comparatively gentle west and south-west winds that blow on the west coast of the peninsula in the previous months. It cannot have taken the south-east trade several months to travel from the Equator to India if the way was clear. Certainly the low pressures over India seem to have invited its approach long before it arrives. Possibly the facts may be satisfactorily explained as follows. The normal trough of low pressure which is the goal of the south-east trade, and which lies somewhat south of the line in January, still remains in an attenuated form near the Equator during the hot season of India, and here the south-east trade ends. North of it there is a belt of slightly higher pressure, separating it from the low-pressure system which is being developed over India by the heat. The north-west winds that blow on to the west coast of the peninsula are derived from the north side of these higher pressures (Fig. 47, left-hand diagr.). As the hot season wears on pressure continues to fall over S. Asia, and much of the air which has expanded and risen makes its way in the upper atmosphere into the equatorial low pressures, which become filled up in June. There is then a continuous and fairly uniform gradient from the tropical high-pressure belt of the south Indian Ocean, right across the Equator, into the low pressures of N. India (Fig. 47, right-hand diagr.). The south-east trades find no obstacle to stop them at the Equator, and sweep on over India as the south-west monsoon. The gradient is steeper than in May, since pressure has been increasing in the anticyclone over the S. Indian Ocean while decreasing over S. Asia, and the wind is very much stronger. The latest isobar maps of the Indian Ocean (*Meteorological Atlas of the Indian Seas*, and the last issues of the *Monthly Meteorological Charts of the East Indian Seas*), show a well-marked high-pressure system in the neighbourhood of the Equator, with light and variable winds in April; in May there is a steady gradient over the south Indian Ocean, but a wide area of little or no gradient between lat. 10° S. and the low-pressure system over India.

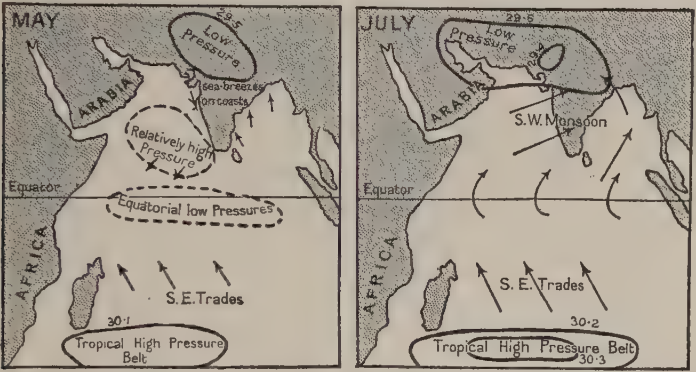

MAY
29·5
Low Pressure
ARABIA
sea-breezes on coasts
Relatively high Pressure
Equator
Equatorial low Pressures
AFRICA
S.E.Trades
30·1
Tropical High Pressure Belt
JULY
29·5
Low Pressure
ARABIA
S.W.Monsoon
Equator
AFRICA
S. E. Trades
30·2
Tropical High Pressure Belt
30·3

FIG. 47. Diagrammatic sketch of the conditions before (left-hand diagram) and after (right-hand diagram) the setting-in of the south-west monsoon.

The summer monsoon blows over India as a fairly steady wind more than twice as strong as the north-east monsoon, and saturated with vapour from its long passage over the tropical ocean. At Bombay its average speed is about 14 miles per hour, but this is more than in most of India. It is still stronger over the sea, especially the Arabian Sea, owing probably to the influence of the low-pressure system of S. Arabia. It reaches the W. coast of the peninsula first, and surges on towards the east and north. It arrives with remarkable punctuality in most years, at the following dates :

Mean date of :	*commencement.*	*ending.*
Bombay . . .	June 5	Oct. 15
Bengal . . .	June 15	Oct. 15–30
N.W. Province . .	June 25	Sept. 30
Punjab . . .	July 1	Sept. 14–21

By July all India is under its influence. The front of the monsoon generally develops into a tropical cyclone in the Bay of Bengal, and often in the Arabian Sea, but once the SW. current has set in the steady movement of air precludes such storms, which are almost unknown till October, when the weak and variable winds of the retreating monsoon again offer favourable conditions.

The main wind direction round India is shown in Fig. 48. There are two well-marked air currents, one meeting the Western Ghats at right angles but not extending far north of the Gulf of Cambay, the other advancing over the Bay of Bengal, and then turning towards the NW. up the Ganges plain. The currents meet and give heavy rainfall over Central India, where there is a long trough of low pressure extending SE. from the low-pressure centre over Sind. No doubt the great wall of the Himalayas plays an important part in directing the SE. winds of the plains, and through them controls the northward limit, and the force, of the Arabian Sea branch of the monsoon. We may note also that the mountain barrier, by preventing the inflow of winds from the dry interior of Asia, causes that from the Indian Ocean to be especially strong. Throughout S. and E. Asia the winds of the summer monsoon arrive charged with moisture from the warm seas over which they travel. China like India has heavy summer rains. But the rain is especially heavy over India owing to the favourable arrangement of the mountain ranges which bound the country. Dr. G. C. Simpson (*Q. J. R. Met. Soc.*, 1921) lays great stress on this feature. The region may be regarded as a compartment, with mountain sides at least 6,000 ft. high on the E., N., and W., but open on the S. to receive the powerful inrush of the moist ocean winds. The air that enters must rise at least 6,000 ft., most of it higher, over India, and the cooling that results from this ascent seems to be the main general cause of the heavy rainfall, the local distribution being determined by the position of the ranges in relation to the wind directions.

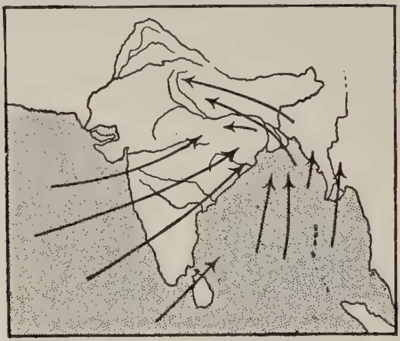


Fig. 48. The main currents of the south-west monsoon.

The south-west monsoon is essentially the rain-giver of India, and the source of livelihood to its millions of inhabitants. It is estimated that 85 per cent. of the total rainfall is derived from it. But it must not be thought that it rains continuously. There are breaks, which are sometimes prolonged, and the total rainfall of the season may be reduced to such an extent that the crops fail and famine follows. The rain is associated with the passage of depressions, comparable with the cyclones of the westerlies, or with those of the cold season in the north of India, but they move in the opposite direction to the latter. They usually form over the head of the Bay of Bengal (Fig. 56) and move along the trough of low pressure up the Plains. The rain falls in copious tropical downpours, but it is noteworthy that in Bengal and Assam violent thunderstorms are rare during the south-west monsoon, this being a striking difference from the conditions of the previous three months when nor-westers with much thunder and lightning were frequent.

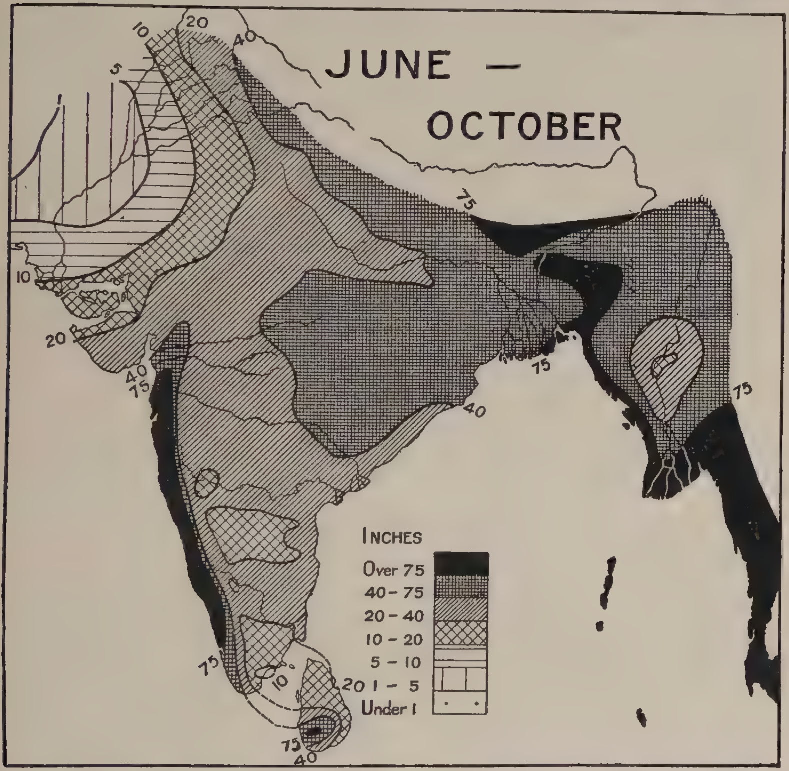


FIG. 49. Mean Rainfall during the season of general rains. (*Climatological Atlas of India.*)

The map of mean rainfall during this season (Fig. 49) shows very clearly the great influence of the relief of the land. The rainfall figures mentioned in the following paragraphs which deal with the monsoon are, except where otherwise stated, the mean totals for the months June, July, August, and September, and thus represent the monsoonal rains. The west coast of the peninsula and Ceylon, and still more the Western Ghats and the hilly interior of Ceylon, have enormous downpours, 50 to 100 inches on the coast, far more on the windward slopes of the hills. This wet strip does not extend far north of Bombay. The Indus delta is arid; Karachi has only 6 inches while Bombay has 76 inches. East of the Ghats there is an extraordinarily rapid decrease; less than 100 miles from the coast the rainfall has diminished from over 100 inches to under 20 inches. The following table illustrates more accurately this striking rain-shadow:

Station.	*Position.*	*Mean Rainfall in inches. June–Sept.*
Mangalore . .	West coast of peninsula	110
Bangalore . .	Interior ,,	20
Madras . .	East coast ,,	15
Colombo . .	West coast of Ceylon	22
Kandy . .	Central Highlands ,,	28
Trincomalee .	East coast ,,	12

Most of the centre and east of the Deccan receives between 15 and 30 inches.

Similarly to the east of the Bay of Bengal there is a remarkably rapid transition from the rainy coast and windward slopes of the highlands of Tennasserim and Arakan with their excessively heavy fall, to the comparatively dry interior of Burma. In the north the Arakan Range joins the Khasi Hills, and here we find the heaviest rainfall, not only of India, but of the whole world. The configuration of the district, therefore, merits study. The Khasi Hills are an east–west range, 150 miles long, with an altitude of about 5,000 feet. In the east they meet the northward continuation of the Arakan Ranges, here trending towards the north-east, with a similar altitude. Hence there is a wide depression, opening to the south-west, between them and the Arakan Ranges. A large part of the Bay of Bengal branch of the monsoon enters the funnel-shaped depression which lies widely open to it, and the air is forced to rise rapidly as the passage narrows. The result is the phenomenal rainfall, which reaches its maximum, so far as records exist, at Cherrapunji. This station is about 200 miles from the Bay of Bengal, but it must be remembered that the intervening tract consists of low-lying land, which is practically a vast lake at this time, owing to the rivers having overflowed their banks. The flood water is warmer than the sea, and the air currents which have blown over it before they reach Cherrapunji contain enormous stores of moisture. Dacca, just outside the mouth of the 'funnel', has a mean rainfall for the monsoon months of 49 inches; Sylhet, in the narrower part of the funnel, but still on low ground, has 106 inches, Cherrapunji at an altitude of 4,455 feet, on the south side of the Khasi Hills above Sylhet, 318 inches. Beyond the ridge the rainfall decreases rapidly; Shillong, only some 25 miles from Cherrapunji, and at a greater altitude, but situated on the northern leeward slope, has only 55 inches, that is to say less than one-sixth as much as Cherrapunji, and at Gauhati, still farther north, in the bottom of the Bramaputra valley, the rainfall is only 43 inches. At Cherrapunji as much as 905 inches once fell in a year (annual mean 428 inches), and 41 inches, twice as much as the mean rainfall for the whole year in the east of England, has fallen in a single day.

Bengal and Assam have a greater rainfall than the rest of India with the exception of the west coasts. The amount is greater in the east than in the west, in the south than in the north. Owing to the moist air and frequent thunderstorms of the hot season that precedes it, the 'burst' of the monsoon is not nearly so clearly marked as on the west coast.

The Plains derive their rainfall chiefly from the Bengal branch of the monsoon. The amount therefore becomes less with increasing distance from the Bay. The following series gives an instructive view of the diminution from Bengal to Sind:

MEAN RAINFALL

Station.	*June–Sept.*
Calcutta	46 inches
Patna	41 ,,
Allahabad	33 ,,
Agra	22 ,,
Delhi	22 ,,
Mooltan	5 ,,
Jacobabad	3 ,,

The decrease becomes specially rapid when we cross the Ganges-Indus divide west of Delhi and enter the Punjab, and in the deserts of Sind we find the most arid region in India. It is a striking fact that the Thar desert lies almost exactly in the centre of lowest pressures, and the scantiness of its rainfall is at first sight surprising. It is the result of the previous history of the winds that enter it (Fig. 50). On the west the air currents come from the north-west, across the arid plateau of Afghanistan and Baluchistan; they become even drier in descending to the plains of Sind, and can yield no rain. The inflow on the east, north, and north-east consists of air which has lost its moisture during its passage up the Ganges plains, and when the air descends into the Punjab, it is dried still more by its descent, so that the Thar desert receives no rain from this quarter. There remains the south coast of Sind. At Karachi the prevailing winds are west and south-west and they are especially strong during the afternoon. Here, then, would seem to be a source of

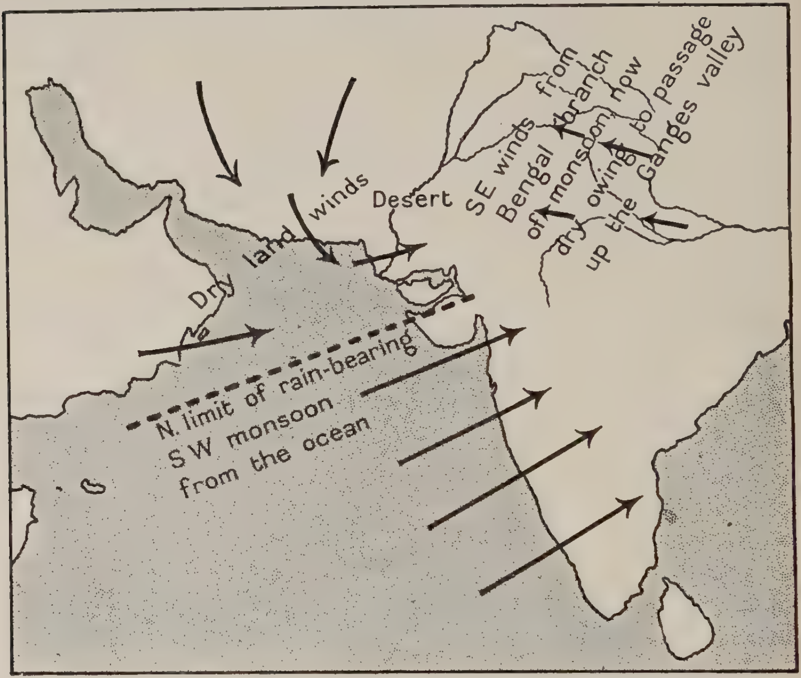

Dry land winds
Desert
SE winds from
Bengal branch
of monsoon, now
dry owing to passage
up the Ganges valley
N. limit of rain-bearing
S.W. monsoon
from the ocean

Fig. 50. The winds round the Thar desert.

rainfall. But these on-shore winds are drawn in from the immediate offing, where the air is by no means saturated with moisture, since it is derived from the north-west current just mentioned as blowing over the plateau of Baluchistan. The wind can pick up but a small amount of moisture during its short passage over the sea, and this is rendered the less effective, so far as rainfall is concerned, owing to the intense heating over the desert sands, itself a result of the cloudless skies. Owing to the heat the air rises and cools, and if the ascent continued high enough dew-point would be reached, clouds formed, and rain produced. But before this can happen the rising air is caught up by the very dry upper current from the west which is known to exist here, and carried away. We must notice that the south-west monsoon of the Arabian Sea, which gives such heavy rain to the Western Ghats, does not reach the deserts of Sind. The northward boundary of this air current is the Gulf of Cambay (see p. 110). If it extended to the mouth of the Indus so that a true monsoon current from the ocean swept up the Indus valley, there is no reason why the rainfall there should not rival that of the equally flat and low-lying Ganges delta. The contrast between the fertility of the Ganges and the aridity of the Indus basin cannot be explained by the difference in the configuration of the valleys.

The arid west, with a mean annual rainfall of less than 10 inches, includes almost all Sind, the west of Rajputana, the south-west of the Punjab, and much of Baluchistan. Jacobabad, on the Quetta railway west of the Indus, has the lowest recorded rainfall, 3 inches during the monsoon, 4 inches during the whole year. Sometimes there is no rain for a year, at other times far more than the mean annual amount may fall in a few hours in a sudden downpour. The mean annual rainfall at Hyderabad, Sind, is 7 inches, but 13 inches fell in the course of three consecutive days in August 1865, 10 inches on one of them. At Doorbaji, Sind, 34 inches fell on one occasion within two days, the annual mean being about 5 inches. These sudden floods are hardly less fatal to plant life than the drought that usually prevails, for they wash away the surface soil here, and cover it up there with sand. They also do great damage to property. Most of the rainfall which goes to make up the mean annual total is of this spasmodic type. The air in the desert is very much drier than in most of India, but the coast has a fairly high humidity owing to the sea breezes. The sky is cloudless, and the heat extreme (absolute maximum at Jacobabad 126°).

The outer ranges of the Himalayas have exceedingly moist air and very heavy rain during the monsoon, which decreases in general from east to west, as on the Plains:

MEAN RAINFALL

Station.	*June–Sept.*
Darjiling	102 inches
Naini Tal	81 ,,
Mussooree	81 ,,
Simla	48 ,,
Murree	35 ,,

The clouds hang low, and these hill stations are often enveloped for days and even weeks at a time. The hills offer no refuge from the ubiquitous rain and moisture of the Plains during the monsoon. The monsoon does not cross the main ranges of the Himalayas. The farther one penetrates beyond the outer ranges towards the interior, the less is the rainfall. The elevated valleys in the heart of the ranges, such as that of the Indus round Leh, have a remarkably low rainfall. Leh itself has only 1 inch during the months June to September.

The rivers roll along in high flood and inundate their low alluvial plains for thousands of miles. The floods in the Punjab are especially destructive. 'About July and August comes the rush of life-giving water to the steaming plains; then is the anxious time for the engineer and bridge maker; then the swelling brown torrent spreads across miles of river bed, curling and eddying with resistless sweep against piers and abutments, licking the neck of the bridge supports, and bringing down heavy batteries of floating timber and uprooted trees.' But 'in the early dry months of summer these channels are frequently nothing but wide white spaces of glittering sand, with here and there a narrow ribbon of gleaming water permeating the width of river bed and offering no difficulty to the passer-by, except where the main channel, narrowed to the dimension of a rivulet, may perchance present an unfordable obstacle.'

Over most of India the air is much cooler during the monsoon, but the range of temperature from day to night is less than during the hot season. The relief from the heat is welcome, but the continued moisture soon enervates the European. Early in June the highest temperatures were to be found over Central India. Here, as in most of India, the clouds and rain of the monsoon cool the air considerably. Over arid Sind, however, where there is but little cloud and hardly any rain, the temperature in July (Fig. 51) is about the same as in June, and is by far the highest in all India. The west coasts of the peninsula and Ceylon are now the coolest regions, since the sea-influence is strong, and cloud and rain are very heavy. In Bengal and Assam the arrival of the monsoon has not so much effect on the temperature, since the previous months are not rainless.

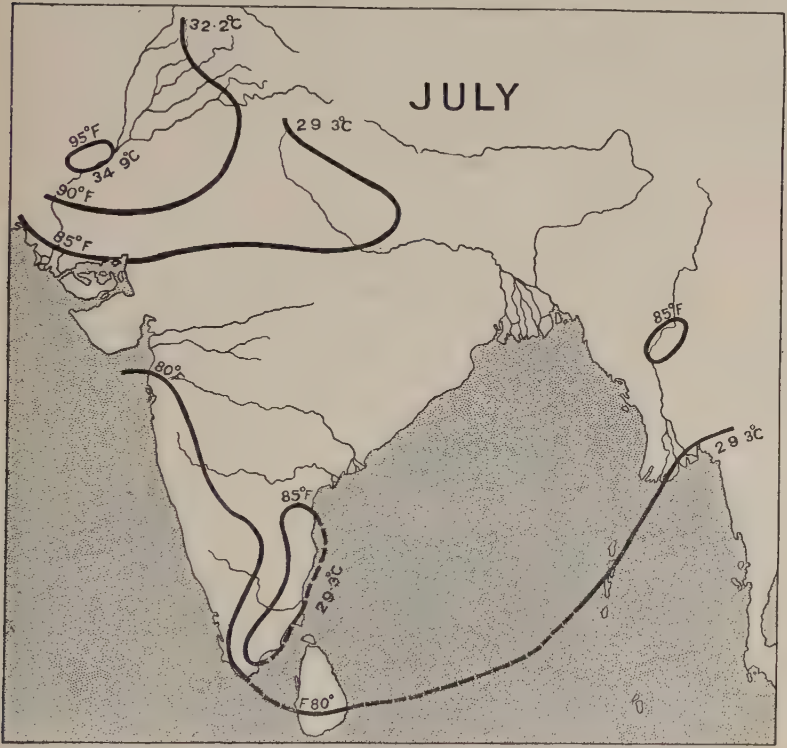


Fig. 51. Mean Temperature. (*Climatological Atlas of India.*)

In a normal year the south-west monsoon continues till the middle of September over the whole of India. About that time the falling temperature causes the atmospheric pressure to increase over the north of India, and the monsoon currents begin to lose their strength, and are no longer able to reach the north-west frontier. The weakening is a gradual process, in contrast to the suddenness with which the monsoon started. By the middle of September the monsoon is over in the Punjab, and by the end of the month it fails to reach the United Provinces. North-west winds take its place and in the beginning of October they extend over Bengal. Bombay is among the last places to lose the monsoon, in mid-October, as it was one of the first to receive it.

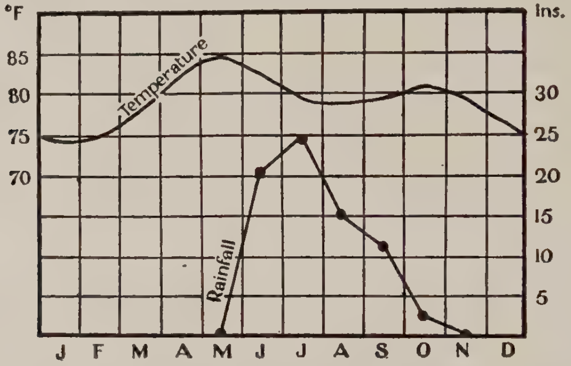


FIG. 52. Mean Temperature and Rainfall at Bombay. The drop in temperature when the monsoon starts, and the rise when it stops, are well marked.

The distribution of pressure over India remains much the same in July and August as in June. In September the low-pressure system begins to fill up, and in the beginning of October the pressure is very uniform. The isobar map for that month shows a slight high-pressure system over north India, relatively low pressures over the Bay, but the gradient is very feeble.

Season of retreating monsoon. As the south-west monsoon withdraws, the sky clears, the sun shines again, and in spite of the lateness of the season, temperature rises for a few weeks, to fall again afterwards to the winter minimum (Figs. 52 and 44). The land is still water-logged with the rains when the heat increases, and consequently this is an unhealthy period.

During November and December the prevailing winds on the east coast of the peninsula south of Orissa blow from the south-east, but they really belong to the retreating south-west monsoon.

'The (south-west monsoon) current then recurves over the centre of the Bay, in the same manner as during the monsoon proper over the north of the Bay and Bengal, and is directed or determined to the west or Madras coast of the Bay, which hence receives frequent rain during a short period of two months—the rainy season of the eastern and southern parts of the peninsula south of Orissa and Ganjam. These rains were formerly described as accompanying the setting in of the north-east monsoon on the Madras coast. That, however, is a misnomer, as the true north-east monsoon winds are dry land winds, and the rain-giving winds of this period in Madras are those of the south-west

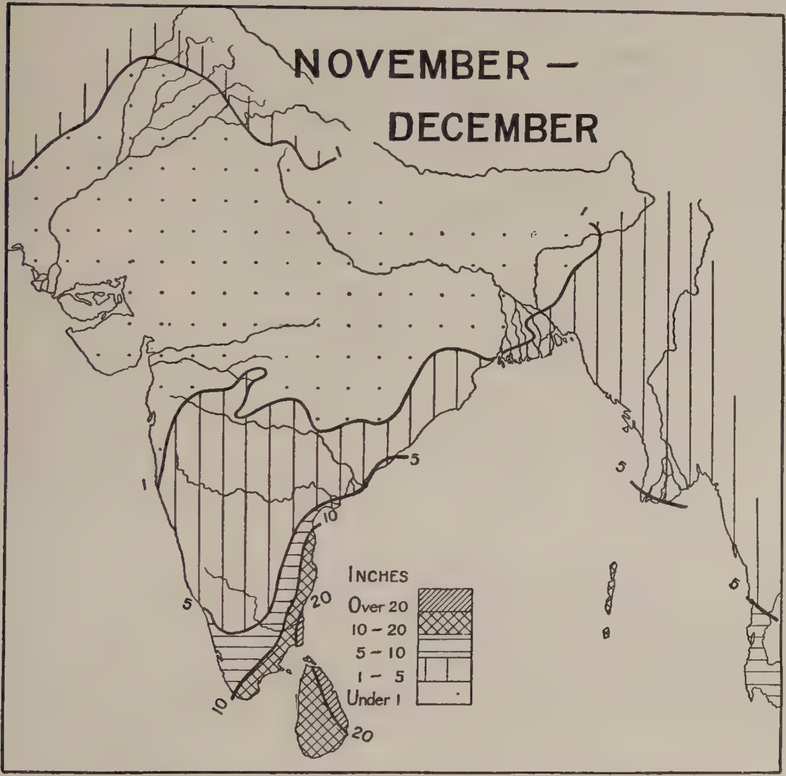


Fig. 53. Mean Rainfall during the season of the retreating monsoon. (*Climatological Atlas of India.*)

monsoon in its retreat or contraction down the Bay. The period during which this rainfall occurs is hence now usually termed the retreating south-west monsoon' (ELIOT.)

These months are the rainiest of the year in the Madras Presidency (Fig. 53). At Madras itself the rainfall is 15 inches for the four months June to September, but 18 inches for the two months November and December. All the east and south-east of the peninsula south of the Godavari delta has heavy rain in November and December, and also the east of Ceylon, where there is a considerable rainfall in January also; but in Madras the rains cease by the end of the year. A considerable portion of the rain of November and December is brought by the cyclones that develop over the Bay during these months.

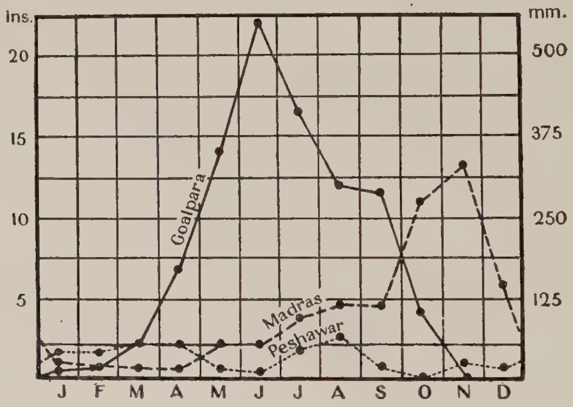


FIG. 54. Mean Rainfall.

It is interesting to note that in every month of the year there is a considerable rainfall in some part of India. In January and February north India gets rain from the winter cyclones (Peshawar, Fig. 54). In March thunderstorms begin to be frequent in Bengal and Assam, and continue to give heavy rain till the monsoon starts in June (Goalpara, Fig. 54). The general monsoonal rains continue till October, and then during the retreat of the monsoon in November and December there is heavy rain in Madras (Madras, Fig. 54.)

The temperature over the whole country is remarkably uniform in October (Fig. 55); the mean is about 80° everywhere at sea level. In November it is becoming cooler in the north, and the nights in the far north-west are chilly; in December the cold weather season starts.

When the monsoon is at its height only comparatively shallow depressions occur, forming at the head of the Bay and travelling inland. True tropical cyclones are rare until the monsoon dies away. At this period the barometric gradient over the Bay is slight, and the winds are weak and variable. These conditions are favourable for the local development of excessive heat and moisture in the stagnant air; pressure falls, and in a day or two a tropical cyclone may form, to move slowly forward on its destructive path. The total number of tropical cyclones recorded is:

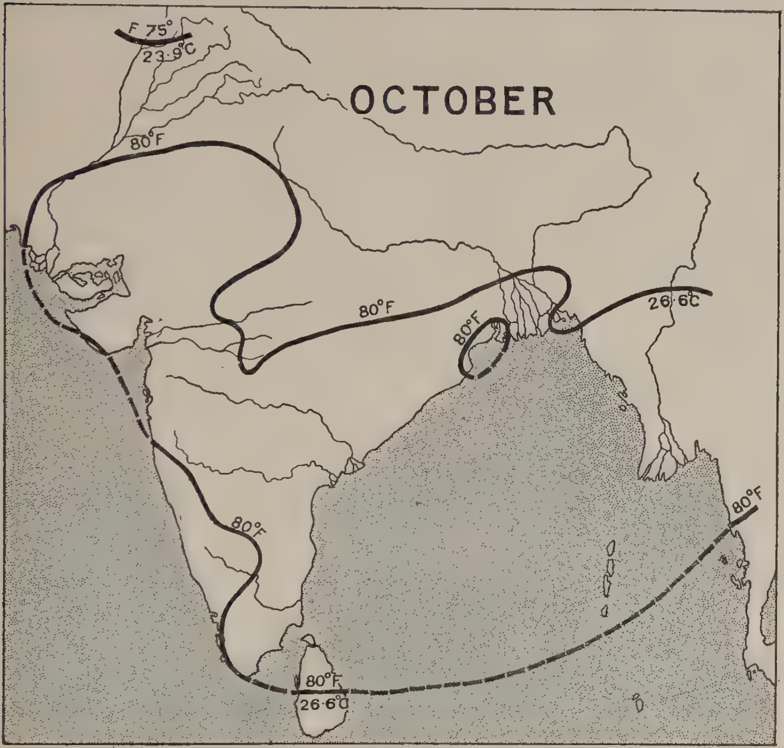


FIG. 55. Mean Temperature in October. (*Climatological Atlas of India.*)

	Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*
Bay of Bengal, 1877–1903 .	0	0	0	1	8	4
Arabian Sea, 1877–1903 .	0	0	0	1	5	6

	July	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Total.*
Bay of Bengal, 1877–1903.	4	2	6	8	17	6	56
Arabian Sea, 1877–1903 .	0	0	0	2	7	0	21

A few of the usual tracks followed by the storms are shown in Fig. 56. The early storms of the year develop in the extreme south of the Indian seas, in about 10° N. lat. The place of origin moves northward with the sun, till in July, as we have seen, it is in the head of the Bay of Bengal, but the storms that originate there are usually not of tropical violence. As the sun returns southward, the place of origin of the cyclones follows it, and in November most of them develop south of 12° N. lat. They usually die out, or at any rate decrease very much in intensity, if they cross any large land area. But while their centre still lies over the sea, they can work fearful devastation on the coasts. The coasts of Madras, Bengal, and Burma especially

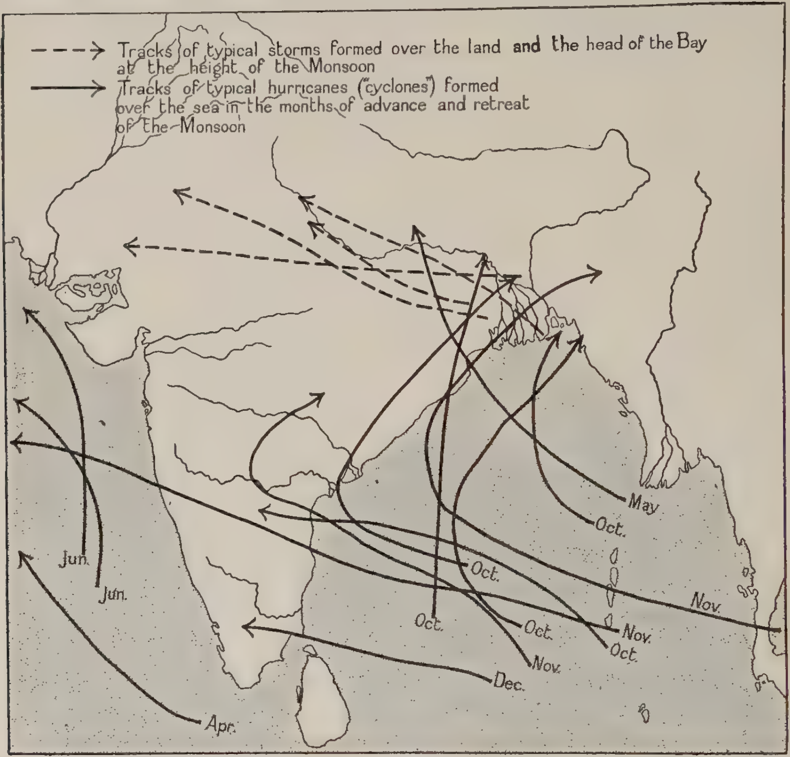

Tracks of typical storms formed over the land and the head of the Bay at the height of the Monsoon
Tracks of typical hurricanes ("cyclones") formed over the sea in the months of advance and retreat of the Monsoon
Jun.
Jun.
Apr.
Oct.
Oct.
Oct.
Nov.
Dec.
May
Oct.
Nov.
Nov.
Oct.

FIG. 56. The broken arrows show the tracks of typical storms formed over the land at the head of the Bay at the height of the monsoon, the full arrows the tracks of typical hurricanes formed over the sea in the months of advance and retreat of the monsoon.

have suffered enormous material damage and thousands of lives have been lost. Cyclones have been known to cross the peninsula from the Bay of Bengal to the Arabian Sea. When this happens they degenerate into feeble storms accompanied by rain during their passage over the land, and develop again into hurricanes on reaching the Arabian Sea.

Droughts. The actual rainfall in any year may be either above or below, often very considerably above or below, the mean for the place. Deficiencies are of most practical importance in India. The deficiency may occur either during the cold season, if the cyclones of north India are few or feeble, or during the south-west monsoon, which may be late in appearing, early in ending, or which may give but poor rains owing to frequent and long spells of clear dry weather. The rainfall is most variable in the arid west, in and around the deserts of Sind, but here deficiencies are not of much importance since there are few crops which depend on the rainfall. It is least variable in the districts of heaviest mean rainfall; here again even the greatest deficiencies matter little, since the mean rainfall is far more than sufficient for agricultural requirements. They are most serious in the intermediate districts with a mean rainfall between 15 and 45 inches and a very dense population. The normal rainfall just about suffices for the crops, and any great deficit causes failure and consequent famine. 'The effect on crop-production is greatest and most disastrous in the following areas: (1) Central Burma, (2) The Deccan, including the Bombay and Madras Deccan districts, and Hyderabad, (3) North-Western and Central India, more especially the South Punjab, East Rajputana, and the United Provinces.' (Eliot.)

When a failure in the winter rains is followed by a poor monsoon in north India, or when, as often happens, the summer monsoon is poor two years running, the consequences to the natives are, of course, intensified. 'A sudden cessation of the rains of 1896 resulted in famine over an area of about 307,000 square miles, with a population of nearly 70,000,000; on the average 2,000,000 persons were relieved daily during the twelve months from October 1896 to September 1897, and the number rose to more than 4,000,000 at the time of greatest distress. . . . In the height of the famine there were for weeks together more than 6,000,000 persons in receipt of relief. On a comparison of the Census figures of 1901 with those of 1891 it is estimated that during these two famine periods the death-roll exceeded the normal mortality of non-famine years by about 5,000,000.'

Climate regions. From the preceding sketch, based on the seasonal changes, it must be obvious how manifold are the climates of India, considered regionally. The north has very different conditions from the south, the coasts from the interior, the west coasts from the east coasts. Altitude introduces further and even greater variations, ranging from the plains through the hill-stations to the everlasting snows of the Himalayas. Fig. 57 shows the major climate regions. Their characteristics have been already indicated, and need not be repeated here. We shall describe as samples only (i) the Carnatic, as representing south-east India and east Ceylon, (ii) Bengal, a moist coastal region, (iii) the Punjab in the semi-arid plains of the northern interior, (iv) Simla, a typical hill station, (v) the Vale of Kashmir, an intermont basin near the front of the Himalayas, and (vi) Leh, in an elevated valley in the far interior of the mountains.

The Carnatic. The climate is distinguished by uniform high temperatures, and moist air throughout the year, and by the fact that most of the rain falls in October and November, during the retreat of the monsoon rather than during the monsoon proper. The term ' cold season ' is a misnomer here for the early months of the year, since the mean temperature of even the coolest month, January, is 75° ; May is the warmest month with a mean temperature of 89° ; June is almost as warm. The annual temperature range is only 13°. The daily range also is small. In January the thermometer usually rises in the day to about 85° and does not fall at night much below 70°, so that the nights are very oppressive in Madras as compared with north-west India. In May the average daily maximum temperature is about 100°, and the average minimum about 80°. The lowest temperature ever recorded was 57°, the highest 113°. The uniform high temperatures are the less bearable because of the great humidity of the air, which ranges from 65 to 81%. April especially is very enervating owing to the hot moist sea winds from the south.

In April and May there are occasional thunderstorms known as 'mango-showers'. The arrival of the south-west monsoon does not cause any very decided increase in the rainfall, since the winds have lost most of their moisture on the west coast of the peninsula; but the rainfall increases slowly till September, which has 5 inches. Then in October it becomes heavier, just at the time when over most of India the rains are stopping and the fine late summer weather is beginning. The retreating monsoon recurves over the Bay as already described, and gives

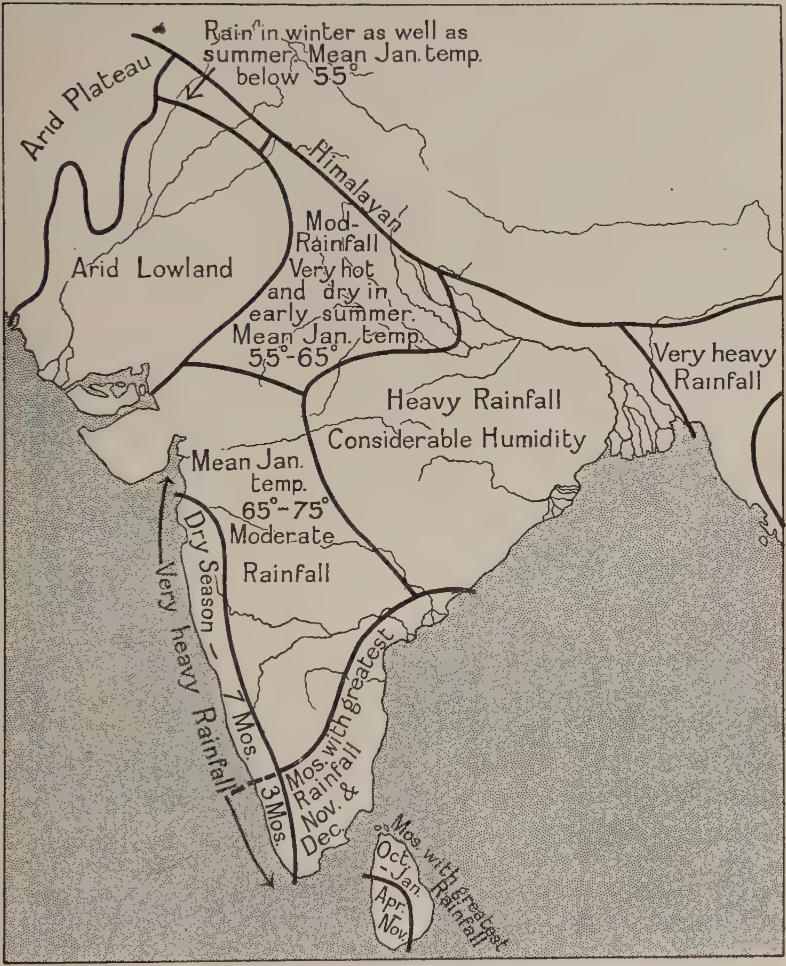

Rain in winter as well as summer. Mean Jan. temp. below 55°
Arid Plateau
Himalayan
Arid Lowland
Mod- Rainfall Very hot and dry in early summer. Mean Jan. temp. 55°-65°
Heavy Rainfall
Considerable Humidity
Very heavy Rainfall
Mean Jan. temp. 65°-75° Moderate Rainfall
Very heavy Rainfall
Dry Season – 7 Mos.
3 Mos.
Mos. with greatest Rainfall Nov. & Dec.
Oct.-Jan.
Apr.-Nov.
Mos. with greatest Rainfall

FIG. 57. The major climate regions of India.

very heavy rainfall to the Carnatic in October (11 inches) and November (13 inches). December has only 5 inches, and by the end of the year the south-west monsoon has entirely withdrawn, leaving Madras under the influence of the dry land-breezes of the north-east monsoon. The rainfall is very slight in January and February, decreasing to a minimum in March. The October, November, and December rainfall is collected in large tanks on which the irrigation of the province depends.

Bengal. Here is the transition between the constantly high temperatures and great humidity of the south of the peninsula and the dry bracing air and great range of temperature which characterize the north-west.

Bengal is low-lying, and there is much inland water, rivers, and creeks, irrigation canals and ditches, and swamps. Moist sea breezes begin in February, and the prevailing winds continue south till October, making the air damp and relaxing. Moreover, Bengal as a whole is one of the rainiest provinces of India.

'The customary division of the year into three seasons, the cool season, the hot season, and the rains, holds good in Bengal as in the more westerly provinces, but the first is shorter and less bracing, and the heat of the second, if less intense owing to the greater dampness of the air, is on this account, perhaps, more trying to the European constitution. The rains are also longer and more copious.' (BLANFORD.) In March and April nor-westers, accompanied by dust- and thunderstorms, give heavy rain. During the hot season Calcutta enjoys an advantage in the fresh sea breeze which lasts through the late afternoon and evening and slightly cools the air. 'At length in the early part of June, the clouds gather more thickly, while the barometer falls to a lower point than it has reached since the beginning of the year ; and in the first or second week, heavy and continuous rain ushers in the monsoon. This first burst of the rains usually accompanies a cyclonic storm, formed either at the head of the Bay or over the delta itself. . . . Its immediate effect is a great fall of the day temperature ; and the comparative coolness, supervening on many weeks of close oppressive weather, brings a sense of relief. . . . When, however, in September the rainless intervals become longer, and the day temperature begins to rise, while the air, still highly charged with moisture, is almost motionless, the relaxed energy of the human system fairly rebels against this further trial of its endurance, and all who are not compelled by their avocations to remain at their post hasten to escape to the temporary refuge of a hill station. September and October are thus the most trying and unhealthy season of the year.' (Blanford.)

Punjab. We reproduce at length an account given by the Rev. J. M. Merk, a resident in the province:

'Like the rest of India, the Punjab has really but three seasons: the summer or hot season, the rains, and the winter, which, in India, we speak of simply as the cold season. The hot season begins in April, but in March it is already so warm that barley and wheat ripen and are harvested. From April to June, as a rule, there is no rain. The west wind holds sway, and blowing from the sandy wastes of the Indus region, is a veritable hot wind. A denizen of the temperate zone can hardly realize the desiccating, truly scorching heat of the wind. When exposed to it, one may imagine he is facing an open furnace. The thermometer rises in the shade to over 120°. In order to enjoy fresh air at this season one must take exercise in the early dawn, between 4 and 5 in the morning; for no sooner has the sun risen than the heat sets in again. After 7 a.m., save of necessity, no European leaves his house, and should business oblige him to do so, he must protect himself from the sun with a sunshade and a thick head-covering. . . . At sunrise, or soon after 5 a.m., houses must be closed, only a small door being left open for communication with the outside world. Thus the house of a European is more like a gloomy prison than an ordinary dwelling house. So long as the hot winds blow strongly and steadily, rooms may still be kept in some measure cool by means of "tatties" or grass screens set up in front of the doorway, and continually sprinkled with water, or by the fan vanes of the so-called "thermantidote", which a servant keeps revolving and sprinkles with water; and at night the punkah is worked. Whoever cannot provide himself with these artificial cooling appliances must suffer the daily torment of insupportable and exhausting heat. Man and beast languish and gasp for air, while even in the house, the thermometer stands day and night between 95° and 115°. Little by little the European loses appetite and sleep; all power and energy forsake him. Vegetation suffers equally; almost all green things wither; the grass seems burnt up to the roots; bushes and trees seem moribund; the earth is as hard as a paved highway; the ground is seamed with cracks; and the whole landscape wears an aspect of barrenness and sadness. At length, in June, the hot winds cease to blow, and are followed by a calm; and now indeed the heat is truly fearful; grass screens and thermantidotes avail naught; all things pine for the rains; but no rain, not even a shower, can one hope for, till the south and east winds shall have set in. And even then, the rains do not extend to the whole of the Punjab; Lahore has but little rain, Mooltan scarcely any; and the peasant of the Western Punjab is dependent entirely on artificial irrigation for the watering of his crops.

The southerly and easterly winds bring first clouds and violent storms with heavy rain showers, which are repeated daily, or, at all events, every 2 or 3 days, and, finally, the rains, which, in the Himalayas, set in at the beginning of July and cease at the end of August or in the middle of September. In July the trees begin a second time to burst into leaf; grass springs up once more, and soon a vegetation is developed that, fostered by warmth and moisture, is scarce to be kept within bounds. The peasant now works hard at ploughing, sowing, and weeding his fields. Rice is sown in June, during the great heat; in September it is reaped, and within two months, maize is sown and harvested. . . .

After from 4 to 6 weeks of heavy rain, often falling uninterruptedly for 2 or 3 days in succession, it clears up, and sometimes some weeks pass without further rain; after which, a week or two more of rainy weather brings the season to a close. Grateful as is the coolness brought by these showers, the more oppressively hot and sultry it is when the rain ceases and holds off, if only for half a day. The atmosphere weighs on one like a heavy coverlet; and then comes the daily and nightly plague of mosquitoes. Insect and reptilian life is now active; of evenings it hums and buzzes and croaks all around; frogs make their way into the house, and with them more serious and unwelcome visitors, scorpions, and snakes; for which reason it is unwise, at this time of year, to go about in the dark.

One can hardly picture to oneself in our European climate how serious and disagreeable are the effects of excessive moisture, as experienced towards the end of the rains. Woodwork swells, and doors and windows can be fastened only with much difficulty. Shoes and all articles of leather become thickly coated with fungus, books become mouldy and worm-eaten, paper perishes, linen becomes damp in the presses, and despite the oppressive heat, one must often light a fire on the hearth, only to neutralize in some degree the influence of the damp.

The period which immediately follows the rains up to October is the most unhealthy season in the year. Decaying vegetation under an ardent sun generates miasma, the consequences being fever, dysentery, and not infrequently cholera. Towards the end of the rains, one rejoices indeed to see the heavy dark clouds disappear, but the heat soon becomes once more so great that one longs for the cold season, and more than ever turns an anxious eye to the wind vane, watching for some sign of the cool westerly and northerly winds. With the beginning of October these winds set in steadily, clearing the skies, and now the blue firmament appears in all its splendour, so glorious in the torrid zone. . . . From October to Christmas, as a rule, the weather is clear and fine, the air is pure and most delicious, and one can hardly imagine a more charming climate; but it must never be forgotten that an Indian sun shines overhead, and that even in the cold season one must never expose the unprotected head to its rays. The European now once more breathes freely, and it is a delight with the head well covered to move about in the open air. For 5 or 6 weeks white men can work vigorously and with pleasure.

In December and January, the fire burns all day long on the hearth, and in the morning and evening is especially grateful. The nights are positively cold; even on the plains, ice and hoar frost form, and near the ground the thermometer sometimes sinks to 23°. During the second half of the cold season we have in the Punjab a good deal of rain, without which indeed the barley and wheat harvest is poor; the pulses also require the winter rains. In February we have a short spring; many trees unfold their leaves, and every bush furnishes its quota of flowery adornment. But this spring is of short duration, and in March it is already warm on the plains and the hot summer is at hand; an occasional dust-storm, however, for a while keeps off the summer heat. A dust-storm is indeed in itself unpleasant, the air being so charged with dust as to bring an Egyptian darkness, no matter what may be the hour of the day.'

Simla is on a ridge in the front ranges of the Himalayas. The seasonal changes are the same as in the Punjab, which Simla overlooks, but the altitude being about 7,000 feet, the temperature is much lower at all times; even the hot season at Simla is pleasant for Europeans, who find it a haven of comfort after the furnace heat of the Plains. The hottest month is June, when the mean temperature is 67°, about the same as in Central Europe in that month; the mean daily maximum temperature is 74°, the mean daily minimum 61°. January is the coldest month, with a mean temperature of 39°, the same as in England. Frost is common at night in winter, the lowest temperature on record being 19°. There are sometimes heavy falls of snow, and occasionally the snow-covering is several feet deep after a bad storm. The air is bracing and, except during the south-west monsoon, dry.

In January, February, and March, the cold season cyclones of north India cause heavy falls of rain and snow, the total precipitation amounting to about 3 inches in each month, twice as much as in the plains of the Punjab. In April, May, and the first half of June there are often thunderstorms with heavy showers of rain. These are the representatives of the dust-storms of the Plains, and indeed they sometimes bring clouds of dust even as far as the hills. They nearly always occur in the afternoons. The air is remarkably dry in April and May, the mean relative humidity being only 45 per cent. The end of June brings the monsoon with the sudden and complete change of weather already described for India as a whole. The rain pours down during July and August, and the crisp dry air of April and May is replaced by the monsoon currents which are always damp and often saturated. The clouds hang low on the front ridges of the Himalayas, much lower in summer than in winter. Simla is often enveloped in cloud for days, even weeks, at a time during the monsoon, and the hill-stations farther east are even worse off in this respect. In the middle of September the rains cease; on the average 50 inches fall during the monsoon. The weather is then beautifully clear, mild, and settled till the end of the year, and the sky is cloudless. This is the most charming season of the year at Simla, and all Europeans who can do so make for it or some other hill-station. It is a favoured resort during the hot season also, but during the rains the ubiquitous damp and heavy rain make it undesirable. In the cold season it has some visitors, but many Europeans find it too cold.

Vale of Kashmir. The vale is a flat-bottomed depression, about a hundred miles long and fifty wide, through which the river Jhelum flows. It is behind the front ranges of the Himalayas, and its climate differs materially from that of the Plains; it resembles rather that of Central Europe. At Srinagar in the centre of the vale, 5,250 feet above the sea, the mean January temperature is 31°, about the same as at Berlin, and considerably less than in England, or at the most frequented hill-stations in the Himalayas, which are some thousands of feet higher. The warmest month is July, not June as in most of north India, with the high mean temperature of 73°. Thus the range of temperature is very great, a common feature in such enclosed basins. The air is always damp, the mean monthly relative humidity ranging from 71 to 82 per cent.; it is highest in the cold months. But the annual rainfall is comparatively small, only 27 inches. The driest months are October, November, and December, each of which has less than 2 inches of rain; the other months have about 3 inches each. The heaviest precipitation is in the early months of the year, and is derived from the winter cyclones. The four months January to April have 14 inches, the four months of the summer monsoon only 8 inches. The summer monsoon does not bring much rainfall beyond the outer ranges of the Himalaya. Most of the winter precipitation in the vale of Kashmir is in the form of snow.

'We are apt to think of Kashmir as part of India, and therefore as necessarily warm. As a matter of fact it lies 34 degrees north of the Equator, in the same latitude as the northern part of South Carolina. In altitude it stands over 5,000 feet above the sea. Consequently the climate is comparatively cool. From November to March it is so cold as to be not only bracing but even rigorous. The spring and fall are mild and delightful, and the summer is warm. The great amount of water spread over the plain for irrigation, and the summer storms on the mountains make that season damp though but little rain falls on the plain. . . The temperate climate of the region, combined with the beautiful scenery, makes Kashmir a most attractive summer resort for the people of India, especially the English.' (ELLSWORTH HUNTINGTON.)

Kashmir seems to be suitable as not merely a summer resort but also a permanent colony for British settlers.

At *Leh* in Ladakh conditions are much less hospitable. We are here 11,500 feet above the sea in the Upper Indus valley, which is settled by a scanty population between the altitudes of 9,000 and 12,000 feet; below 9,000 feet there are impassable gorges, above 12,000 feet the climate precludes agriculture. The mean annual atmospheric pressure at Leh is about 20 inches. The mean temperature for the year is 41°, for January 17°. The four winter months have a mean below 32°. The lowest temperature on record is −19°, and the mean daily minimum in January is 9°. Temperature rises rapidly as summer comes on; in July the mean is 63°, and the mean daily maximum is 78°. Thus the range of temperature is very great. Water has been made to boil (boiling point 191°) by simply exposing it to the sun in a small bottle blackened on the outside, and shielded from the air by inserting it in a larger vessel of transparent glass. The rays of the sun are very powerful, but the shade temperature at the same time may be low. The precipitation is remarkably scanty. The total for the year is only 3 inches, and no month has over half an inch. The maximum is in the summer, July and August having half an inch each. There is a secondary maximum in winter. The mountains round about must have a very much heavier fall. Snow sometimes lies very deep even in the valley in winter. Agriculture depends entirely on irrigation. The mean relative humidity is low, below or only just above 40 per cent, from May to November; in the winter months it rises to 70 per cent. The air is thus usually dry, and always bracing.

CHAPTER XXI

CHINA

Detailed information concerning the climate of the Chinese Empire is very meagre. Scientific observations are few, and most of the stations at which they are made are on the coasts; the interior is but poorly represented. Few travellers have given any but the most general remarks on the climate, and the inconsistencies we find between some of them show that the statements are based on too brief periods of observation. Hence only the main outlines, without local details, can be described here.

In winter atmospheric pressure is very high over Central Asia, and the gradient over China steep (Fig. 31). Strong winds blow out from the deserts of the interior, which are very cold at this season, and descend as a great cataract over the plateau edge to China. Their descent warms them somewhat, but still they are felt as icy blasts, especially over northern China. They are so strong that they carry clouds of dust, and on the China Sea navigation, even by steamboats, is often interrupted. The mean wind direction is north-west in north China, north in central China, and north-east in the south. Over the China Sea, this monsoon usually commences as a gale which continues for several days.

The winter monsoon is at its strongest in December, January, and February. In April the high-pressure system over Central Asia is breaking up, and the winds over China are variable, though, in general, still from the north-west in northern China; in southern China the summer monsoon is starting, and the prevailing winds are south-east and east. In May the summer low pressures are already developed over the interior of the continent, and they deepen in June and July. The prevailing winds over all China are south and south-east, warm and rainy. They are not of great force, in general only half as strong as the winter winds, for the barometric gradient is not steep; this is an interesting contrast to the conditions in India, where the summer monsoon winds are more than twice as strong as those of the winter monsoon. The low pressures into which the south-east winds of China blow are a great secondary extension from the centre of lowest pressure in north-west India.

The summer monsoon, the season of rain and cloud, comes to an end in September. In October the barometric gradient is reversed, and the dry winds from the interior begin to blow.

The wind reversal from winter to summer is striking:

North China. Percentage Wind Frequency (Hann)

	N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*
Winter . .	17	8	5	6	6	8	18	32
Summer . .	10	9	12	26	16	10	7	10

In winter especially, the direction is remarkably constant, and hence the mean temperature is very low, since the almost constant west, north-west, and north winds blow from precisely the coldest quarter, viz. north-east Asia. In summer the prevailing winds are from the warmest quarter. But over the China Sea the normal monsoon is often interrupted, both in summer and winter, by winds of gale force from other quarters.

China has, in its most marked form, an 'east-coast' climate. The January isotherms (Fig. 30) fall gradually southward in their course from west to east over Eurasia, and attain their most southerly position only just before they reach the Chinese coast, indeed, according to some isotherm maps, on the coast itself. The 32° isotherm touches its lowest latitude for the whole globe, 35° N., in the east of Eurasia; it runs farthest poleward on the west of the same land mass. All northern China has a mean

January temperature below freezing-point. At Hong Kong, situated just inside the tropic, the mean for the coldest month, February, is only 58°, the lowest mean known near sea-level in the same latitude in the north hemisphere. Frost and snow occur everywhere in China, even at Hong Kong and Canton, where, however, they are rare. At Shanghai 10° has been recorded. The low winter temperatures are the result of the lack of a good mountain barrier against the north-west winds, China presenting in this respect a great contrast to India, which is sheltered by the Himalayas. The coasts of China are more exposed than the interior where there are mountain ranges running from west to east, at right angles to the prevailing winter winds. The valleys between the ranges are somewhat sheltered and hence are not so cold as the coasts. Thus in the Yangtse valley, at Shanghai on the coast the mean January temperature is 38°, at Hankow about 500 miles up the river, 39°, and at Cheng-tu, in the Red Basin of Szetchuan, 44°; Cheng-tu is 1,500 feet above the sea, but it is well sheltered by the mountain ranges which buttress Tibet on the east. The whole of the Red Basin enjoys comparatively mild winters; snow and frost are practically unknown, but nearer the sea the Po-Jang Lake in Kiangsi often has a thick sheet of ice in winter. In the north of China even rapid rivers, such as the Hoang-ho in Kansu, are usually frozen in winter.

There is a great difference in temperature in winter between the north and south of China, Hong Kong being 36° warmer than Peking in January. The difference between the temperatures of Fort William and Lisbon, almost the same latitudinal distance apart on the west coast of Eurasia, is only 10°.

The north-west winds descending from the deserts of the interior are of course very dry. The mean relative humidity at Peking in winter is 58 per cent. The sky is almost cloudless, and there is no rain. When the wind blows strong it carries with it clouds of dust, which are a noted scourge of Peking, and are often met with hundreds of miles out to sea. A milder form of the same visitation is the almost constant dust haze. The dust on settling forms the characteristic loess of the north of China. As a rule these dusty storms are confined to the winter months; but 'steady westerly gales often prevail day and night, with but a day or two's interruption at intervals, throughout the months of March, April, May, and on into June. The result of these long-persistent, hot, dry land-winds is not only to render Peking almost uninhabitable at that season with any comfort, but so to parch up the country that a view across the western hills over brown burnt-up grass and the dry parched plain is one of mid-winter, and, but for the heat, it is hard to realize that the month is June. On such occasions it is pitiful to see the winter wheat only sprouting above the ground to wither and die, and the country people walking round their fields with bunches of the parched stalks held in their hands above their heads for Heaven to witness and relent.' (LITTLE.) In Central and South China droughts are almost unknown.

In summer the temperature is remarkably uniform; the July mean is 79° at Peking, 80° at Shanghai, 82° at Hong Kong. The range from winter to summer is great, 55° at Peking, 43° at Shanghai, 24° at Hong Kong.

Summer is the rainy season. The winds of the south-east monsoon have travelled far over the warm ocean, and become saturated with moisture. The total rainfall for the year is greatest in the south and east, and diminishes towards the north and the interior. The coast south of the mouth of the Si-kiang receives over 80 inches per annum. The 40-inch isohyet runs along the north of the Yangtse basin. The north of China, including Peking, has about 25 inches. The rains swell the rivers and the resulting floods are sometimes very destructive to life and property. The Yangtse rises as much as 70 feet in August at Chungking. The average rise at Hankow is about 40 feet.

Over all China most of the rain is brought by the summer monsoon, but we must distinguish three rainfall régimes, those of north, central, and south China; in north China we include all China proper north of the Yangtse basin, central China is the Yangtse basin, and south China all the country south of the Yangtse basin (see rainfall curves for Peking, Shanghai, and Hong Kong, Fig. 58). The conditions are simplest in north China. At Peking 22 inches, 91 per cent. of the annual total, falls in the months May to September. The other seven months of the year have each less than 1 inch of rain. The rainfall increases from the setting in of the summer monsoon till July and August, and then decreases again as the monsoon weakens. This is a typical monsoonal régime.

In south China the régime is somewhat similar, but the rainfall is far heavier than in the north. At Hong Kong the mean annual rainfall is 84 inches, and no month has less than 1 inch. Heavy rain begins at the end of March, and increases to an early summer maximum in June. Each month during the summer monsoon has more than 3 inches of rain, and each of the five months May to September has more than 12 inches. Thus the main features of the rainfall régime in south China are the heavy summer rains, the early summer maximum, and the fact that some rain falls in the winter months, though the amount is insignificant by comparison with the large annual total.

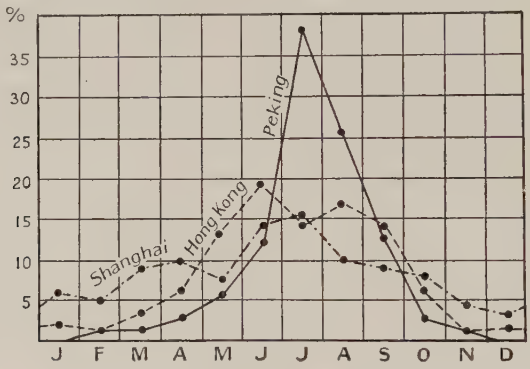


Fig. 58. Mean monthly Rainfall (percentage of the yearly total).

In the third régime, that of central China, most of the rain is derived from the summer monsoon, but the periodicity is not nearly so strongly marked as in north China. At Shanghai, only 57 per cent. of the total falls in the five months, May to September. No month of the year has less than 1 inch. The rainiest months are July and June, and there is considerable precipitation in the winter months. The typical monsoonal régime is much modified. In the interior, e. g. Ichang, there is less rain in winter, about the same amount in summer, 78 per cent. of the total falling in the months May to September.

We add some figures to show more clearly the contrast in winter in the rainfall conditions at Shanghai and Peking.

	Shanghai. Rainfall.		Peking. Rainfall.	
	Total Amount.	*No. of Days.*	*Total Amount.*	*No. of Days.*
	Inches.		Inches.	
January	2	12	0	2
February	2	9	0	3
March	3	13	0	4
April	4	15	1	4
May	4	11	1	7
June	6	14	3	11
July	6	13	9	14
August	6	11	6	11
September	5	11	3	8
October	3	11	1	3
November	2	7	1	3
December	1	6	0	2
Year	44	133	25	72

At Shanghai the mean relative humidity exceeds 75 per cent. in every month. The summer months have the highest mean, 84 per cent., but January and February have 79 per cent. At Peking, the relative humidity in winter is only 58 per cent. (49 per cent. in April), in summer it is 71 per cent. The amount of cloud at Shanghai is greatest in June, 7·4 (expressed in tenths of the sky covered), but it is 6·3 in January and 6·8 in February. At Peking it is only 2·1 in winter, 4·9 in summer.

It is not possible to give a complete or satisfactory explanation of the peculiarities of the rainfall of central China with the data available. With regard to the early summer maximum we may note that this is common to Japan and most of the other islands off the coast of China. In Japan these early rains are known as ‘Plum rains’ (p. 142). It seems clear that in the early summer shallow depressions form in the middle of the Yangtse basin, move slowly seaward down the valley, and then travel to the north-east, over Japan. Their exact origin cannot be said to be understood. The rapid but unequal heating of the wide plains of Szetchuan, which slope south, and are, therefore, well exposed to the sun's heat, is perhaps the most probable of the causes that have been suggested. The secondary maximum of rainfall in August is due to the typhoons, which are most numerous off the coast of central China in that month. Usually they recurve towards the north-east before they reach land, but sometimes they pass right over the coast, which suffers fearful havoc from their fury (p. 146). They are always accompanied by heavy rain even at a considerable distance from the centre.

The winter rain of central China is caused by shallow cyclones which form in the interior of the country, and move seaward, frequently down the Yangtse valley, as in summer. The winds on the east side of the depressions are east and south-east, and blowing from the sea, they are rainy and comparatively warm. In the rear there are strong north winds, an intensification of the usual north-west monsoon. The eastern half of Korea receives a few inches of rain in winter owing to its facing the north winds of the winter monsoon, but the heaviest rains fall in summer.

In conclusion we sum up the main features of the three major climate regions of China. The first region, China, north of the Yangtse basin, is very cold in winter when strong dry north-west winds from the interior of Asia blow almost continuously. The wind often rises to gale force, with clouds of dust. The range of temperature is great, for the summer months are almost as warm as in south China. The monsoonal change of wind and weather is complete. Winter is almost rainless ; the south-east winds of summer bring the rain, which is heaviest in late summer. But the total rainfall is smaller than in the rest of China.

Central China also has cold winters for the latitude, but not so cold as north China ; the mean sea-level temperature is above 32°. The monsoonal change is not so sharply marked as in north China, for the winter months are damp, and have some rain, though not so much as falls during the summer monsoon. The Red Basin of Szetchuan is warmer in winter than the coast, which is more exposed to the north winds ; frost and snow are said to be rare in winter in Szetchuan, and the province is very fertile. The Yangtse valley itself is damp and cloudy, especially in winter ; at Chungking, the sun is often not seen for weeks together. But the rest of the province, lying well above the river level, enjoys clear skies and very fine weather. The climate of Cheng-tu is described as delightfully bright and dry in winter. The name of the province Yunnan denotes 'south of the clouds', with reference to the cloudy valley of the Yangtse. Yunnan is said to be remarkably sunny during most of the year. The summer rains last from the beginning of May till the end of September. Most of the province is more than 6,000 feet above the sea, and is therefore very healthy for Europeans. But the deep valleys in the west are extremely malarious and are avoided as far as possible even by the natives.

The third region, including all China south of the Yangtse basin, is subtropical in character, but has remarkably cool winters for the latitude. The total rainfall is very heavy, and by far the greater part is derived from the summer monsoon; winter, however, is not rainless. The rainiest month is June. Frost and snow are very rare near sea level.

CHAPTER XXII

JAPAN

JAPAN shares in the monsoons of eastern Asia and resembles China in the main features of its climate, most of the rain falling in summer and the range of temperature being considerable. The prevailing winds are north-west in winter, south-east in summer. But modifications are caused by the insularity of Japan. The winters are milder than on the mainland, the 32° isotherm for January being 250 miles farther north; the mean temperature in January at Vladivostok is 5°, at Sapporo, in the same latitude beyond the Japan Sea, 21°; at Shanghai 38°, at Kagoshima 45°. The warm Kuro Siwo influences Japan, but it does not raise the winter temperature very much since the main current flows on the east of the islands which is in lee of the prevailing winds in winter, the season when a warm current is most effective in warming the winds that blow over it; the British Isles are much more favourably situated in relation to the North Atlantic drift over which the winds have blown for two or three thousand miles before reaching Europe at a temperature abnormally high for the latitude. In the case of the Kuro Siwo the main influence is indirect. In winter as well as in summer the warm water is the path of cyclones, which give unsettled weather with some southerly winds and a certain amount of rain to Japan even in winter.

The north of Japan is washed by the cold Okhotsk current, one branch of which makes its way south as far as lat. 37° N. in winter on the east coasts.

The warmest month is August, an insular characteristic. The summers are almost as warm as in the same latitudes in China.

The Japanese archipelago is of great extent from north to south ; Sakhalin lies off east Siberia, the tropic of Cancer passes through Formosa. Very great diversities are due also to differences of altitude, for Japan is essentially a land of mountains.

We may distinguish four main climatic regions, Yezo, Hondo, Kiushiu and Shikoku, and Formosa. They differ chiefly in the intensity and duration of the winters (Sanders).

Yezo has the coldest winters, for there are not less than three months with a mean temperature below 32°, when the land, especially in the north and east of the island, is snow-covered even near sea-level. The cold is not of the dry, crisp type of Siberia, for owing to the influence of cyclones the island has damp air, and a good deal of snow and rain, the precipitation exceeding 2 inches in every month. After a more or less severe five months' winter, very severe in the mountains, there is a quick transition to summer, and in August the mean temperature is 70° in the south, 60° in the north of Yezo. Summer is the rainy season. The annual rainfall is less than in the rest of Japan, being under 30 inches in the north.

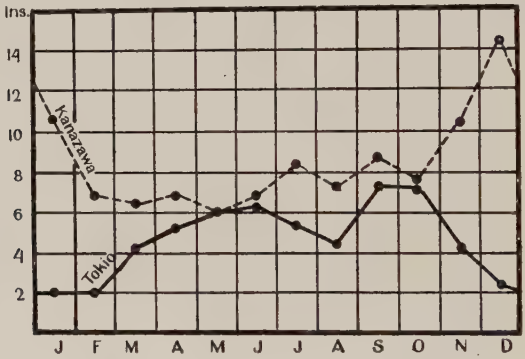


Fig. 59. Mean Rainfall.

In Hondo the winters are much less severe ; only in the extreme north and in the mountains is the mean temperature in January as low as 32°, and in the south it is 40°. But readings of 20° occur at Tokio in most winters, and frost may occur even in April. In summer also it is appreciably warmer than in Yezo, the centre and south of Hondo having four months with a mean temperature above 70°. The summer rains are heavy, and fall mostly in early and late summer. This is a season of moist air and much cloud, frequent rain, and enervating weather. Tokio has more than 4 inches of rain each month from March to November inclusive, and the annual total is 60 inches. The winter conditions are different on the east and west sides of the island; the prevailing winds are north-west, dry when they leave the continent, but humid and somewhat warmer after the passage of the Sea of Japan. Meeting the mountainous west of Hondo they rise and give heavy precipitation, rain near sea-level, snow in the interior, and the weather is very unpleasant, damp, cloudy, and foggy. The winter precipitation is much heavier than the summer, for the prevailing south-east winds of summer are off-shore (Fig. 59).

‘The masses of snow which accumulate in the mountainous region and even on the west coast of Japan are enormous. There are villages which frequently experience a fall of over 20 feet of snow. I was surprised several times by the first snows when trying to get across a mountain pass. In such cases retreat was a necessity. During the winter people in the mountains of course do very little work. I know a village in the north of the main island, called Kiriake, where the inhabitants after their breakfast go to the baths, which are fed by hot springs, and remain in them for the whole of the day enjoying the heat.’ (NAUMANN.)

The highest summits bear snow most of the year. But after crossing the mountains the winds descend to the east coast and give generally clear, sunny, and pleasant weather, especially on the south-facing slopes. Rain, however, is by no means rare, for the warm waters off the south-east of Hondo are much frequented by cyclones which give Tokio more than 2 inches of rain in each of the winter months, but the summer rains from the monsoon winds are much heavier.

Rice is the characteristic crop of Hondo, and in the south and centre cotton and tea flourish. Wheat and barley are grown as winter crops harvested in June.

Kiushiu and Shikoku have a subtropical climate, the mean temperature of the coldest month being well above 40°, and nine months have a mean above 50°. The summers are not much warmer than in Hondo, but the humid air is rather more enervating, and the rainfall a good deal heavier, except around the Inland Sea where there is less than 40 inches.

'On the ocean side of Southern Japan, the palm tree, the orange tree, and the camphor tree flourish. Some small islands near this coast may be found covered with flowers at the beginning of February, when the lake of Suwa in the interior of the main island is frozen over so firmly that fairs are held upon it.'

In Formosa we may say there is no winter; the coolest month has a mean temperature above 60°, and frost and snow are unknown near sea-level owing partly to the low latitude, partly to the winds blowing from the north-east, over a warm sea, instead of the north-west as in most of Japan. The summers are rather warmer than farther north, and there are seven months with a mean above 70°. The rainfall is heavy, and there is the usual monsoonal summer maximum, but the winters are by no means dry, having more than 3 inches in each month. The mountains which cover all the interior rise straight from the sea to over 10,000 feet, and have very heavy rain in winter and summer from the easterly winds.

The summer rain of Japan. The south-east monsoon naturally gives the heaviest rain in the east and south, and the south coasts of Kiushiu and Shikoku have more than 80 inches in the year. But the heaviest rain occurs not when the monsoon is at its height but in June and September. The wettest period is the second half of June and the beginning of July. During these weeks the sky remains wholly overcast, rain falls every day, and the weather is depressing and unpleasant. The air is so moist that walls, pavements, &c., become wet, and furniture and clothes get mouldy. This rainy spell is called the 'Bai-u', meaning plum-rains, as it comes when the plums are ripening; it is the most critical period for rice cultivation. The summer rise of temperature is considerably checked by the pall of cloud of the Bai-u.

The early summer maximum is found not only in all Japan except Yezo but also at Hong Kong, in Central China, the Lu-chu Islands, and Korea, but not in north China and Manchuria, nor in the Bonin Islands. In Japan the Bai-u rainfall is about the same on the east and west coasts, diminishing towards the north.

Okada points out that the monsoon is not at its strongest during the Bai-u, but is weak and often interrupted by calms and light variable winds. He suggests as an explanation of the heavy rain the frequent shallow depressions which originate in South China or in the neighbourhood of Formosa, and travel very slowly through the area. He says ‘ the cyclones are perturbations of heat origin, and develop as a result of unequal heating of the earth’s surface by strong insolation. Most of the Yangtse depressions develop in the province of Szetchuan.’ The explanation seems hardly adequate.

The second rainfall maximum, in September, is due largely to the typhoons which pass over or near Japan in that month (p. 146). They tend to form over the sea to the east of the Philippines, and to move first to the north-west and then to the north-east, following the warm waters of the Kuro Siwo. Indeed the Kuro Siwo is a favourite course for depressions all the year, a fact which helps to explain the absence of a dry season in Japan.

The rainfall is heavy over the whole of Japan during the south-east monsoon, heaviest on the south-east and south coasts. Almost everywhere this is the rainiest season of the year, except on the west coast of Hondo. The annual total also is greatest in the south of Japan, that is on the south coasts of Kiushiu and Shikoku, where it exceeds 80 inches, and on the west coast of Hondo, where the Noto peninsula and its neighbourhood have a similar amount. The lowest rainfall is in the extreme north of Yezo, where it is less than 30 inches, and around the Inland Sea, where the surrounding hills reduce the total to less than 40 inches.

CHAPTER XXIII

SOUTH-EAST ASIA AND THE EAST INDIES

The warm seas in which the East Indies are set help to intensify the uniformly hot and moist equatorial climate. The annual range of temperature is very small, 2° at Batavia, 3° at Singapore. The seasons, where seasons are of any significance, depend not on temperature but on the amount of rain. The archipelago lies between the great monsoon areas of south-east Asia and north Australia, and the monsoonal air currents which control the seasons in those countries pass over them (Fig. 60). There are, however, endless local peculiarities, almost every one of the numerous straits and channels being known to mariners for its own squalls or other weather features. Thus the Malacca Straits have 'Sumatras', strong squalls with violent thunder, lightning, and rain, which occur by night during the south-west monsoon. The hot seas and the many mountains cause the rainfall to be very heavy, and the region as a whole is one of the rainiest on the earth. The west of Java has the highest totals, many of them over 200 inches. The west coast of Sumatra is also very rainy. The least rainy islands are Timor and its neighbours in the east of the Lesser Sunda Group.

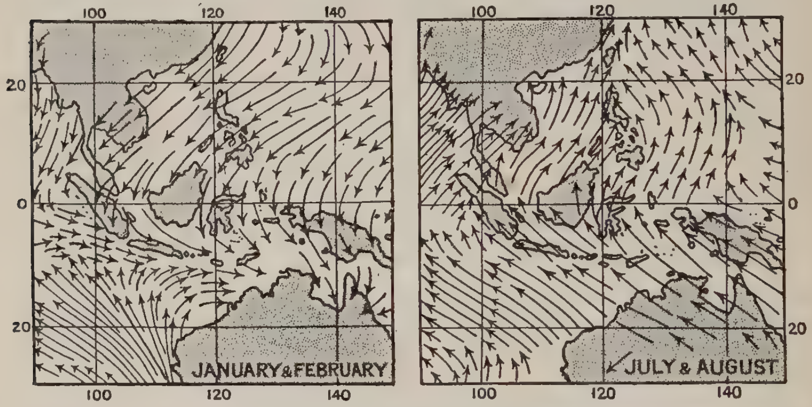


Fig. 60. The prevailing winds of the East Indies region; the longest arrows denote the most constant winds.

The rainfall seasons are different in different islands and even on the two sides of the same island in some cases. Latitude accounts for many of the differences, some of the islands being in the north, some in the south hemisphere. But there are many local differences which are due to purely local causes, such as the lie of the mountains and the trend of the coast. The influence of mountain ranges is important everywhere. Thus Bangkok in Siam has the normal seasons of India, with rain in the northern summer, but the coast of Annam, backed by a mountain range at right angles to the winter monsoon which blows from a warm sea, receives its rain in the winter months. The same contrast is found between the west and east sides of some of the Philippine Islands. But, speaking generally, south-east Asia has its rains in the months May to October, and there is a pronounced dry season in winter, especially in December and January. Penang, on the west side of the Malay Peninsula, has a similar régime, but the dry season is less dry, the driest month, February, having 3 inches of rain. At Singapore, only 100 miles north of the Equator, the dry season may be said to have disappeared, for there is heavy rain in every month; December has most, 10 inches, and there is a secondary maximum of 7 inches in May; the driest month, February, has 6 inches; the relative humidity probably exceeds 75 per cent. in every month; the seasons in the north of Sumatra are similar. The northern half of Borneo shares this equatorial climate; at Sandakan in British North Borneo the driest month, April, has 4 inches of rain. The rainiest months are November, December, and January, with more than 16 inches each, during the north-east monsoon; the mean annual range of temperature is only 3°.

At Batavia, lat. 6° S., the seasons are those of the south hemisphere. The rainiest months are October to April, and July, August, and September are decidedly drier, August the driest month having only 1 inch. Towards the east of the Lesser Sunda Islands the north Australian régime becomes more and more prominent, and Timor and its neighbours have a very dry season in the southern winter. The seasonal change appears to be greater here than anywhere else in the Archipelago; the rain is brought by the west winds; the south-east trades, dry when they leave Australia, have not time to pick up much moisture before they reach the islands. New Guinea also gets its rain from the north and north-west winds of the southern summer, but at some stations the seasons are reversed, the rain being brought by the south-east trades, owing, presumably, to the lie of the mountains in relation to the wind direction.

Van der Stok, director of the Batavia Observatory, divides the East Indies into three main rainfall provinces :

(*a*) North Sumatra and the northern half of Borneo have the Indian régime, most rain in August with south-west winds, least in February.

(*b*) In the neighbourhood of the Equator the rain is heavy all the year, and the humidity high.

(*c*) The south of Borneo, the south of Celebes, Java, and the rest of the Sunda Islands have most rain from November to April, least from May to September when the south-east trades blow. In the eastern islands there is a pronounced dry season.

Typhoons. Fig. 61 shows the usual place of origin and the courses followed in the different months by these devastating storms. They belong to the class known as hurricanes in the West Indies region and as cyclones in the Bay of Bengal, and their meteorology and characteristics are almost exactly the same. According to a recent report (1919) of the Weather Bureau of the Philippine Islands typhoons are :

frequent from July to November,
less frequent in May, June, and December,
quite rare in January, March, and April,
almost entirely absent in February.

It will be seen from Fig. 61 that some typhoons travel almost due west and reach the coasts of Indo-China, and others recurve on a parabolic course, following more or less closely the Kuro Siwo ; the latter degenerate into the ordinary extra-tropical cyclones of the westerlies before reaching Japan. The Philippine Islands are unfortunate in lying right in the track of a large proportion of the disturbances during their most violent stages. We note also from the figure that typhoons have a tendency to originate farther south and to follow a more southerly course when the sun is farthest south. But it must be remembered that here as in other parts of the globe cyclones are prone to be very erratic both in the speed and the direction of their movement ; the tracks shown in Fig. 61 are very much generalized. The following extract from the report of the Weather Bureau of the Philippine Islands on a typhoon in December 1918 illustrates this :

'From the fact that on December 18th to 20th there was a marked increase in the strength of the north-east wind at the Island of Guam (13° N., 144° E.) it is inferred that the typhoon was already developed, though it must have been centred more than 400 miles to the southward. The important indications at Yap (9° N., 138° E.) were the changes in the direction of the wind and the break in the weather. During the 17th to the 19th the wind was north-east, on the 20th it had veered to ENE., then to east in the early hours of the 21st, and after sunrise to south-east. With these wind changes the sky became overcast, with rain squalls, and during the 20th nearly 2 inches of rain fell. . . . By the morning of the 22nd the north-east wind over the Philippine Islands was backing north and north-west, and at 9.30 a.m. a warning was issued " There is a typhoon over the Pacific about half-way between the Western Carolinas and Mindanao, probably moving WbN ". . . . The typhoon now became much more pronounced, and successive reports showed that until 6 a.m. on the 24th the core of the system was following a north-westerly course,

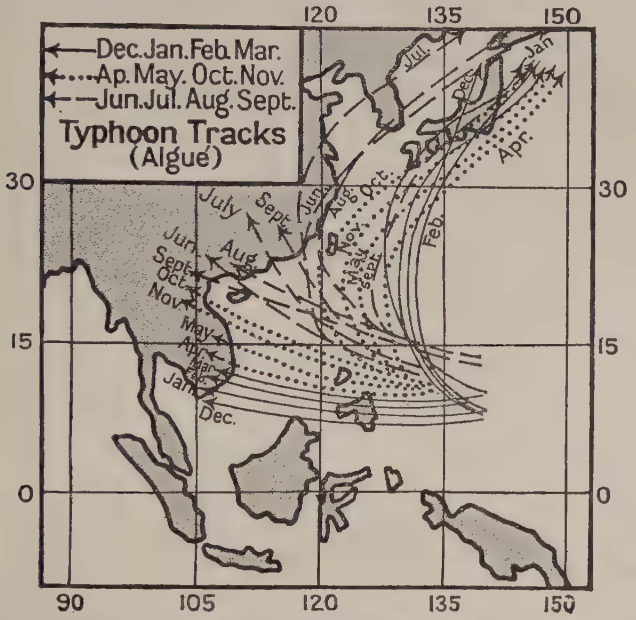

Dec. Jan. Feb. Mar.
Ap. May. Oct. Nov.
Jun. Jul. Aug. Sept.
Typhoon Tracks
(Algué)
120
135
150
30
15
0
90
105
120
135
150
Jul.
Jan
Dec.
Apr.
July
Sept.
Jun.
Aug.
Oct.
Feb.
Nov.
May
Sept.
Jun.
Sept.
Oct.
Nov.
May
Apr.
Mar.
Jan.
Dec.

FIG. 61. Some Typhoon tracks of the China Sea (much generalized).

and having reached 14°N., 128°E., the authorities were convinced that it was curving away to north and north-east, and would soon cease to affect the islands, and before noon on the 24th they did not hesitate to order the typhoon warnings to be lowered. However, suddenly, and without any definite premonitory signs, the north-westward advance was arrested, and the afternoon observations showed that the centre was moving WSW., and to the surprise of the authorities it maintained this unusual course across the middle Philippine Islands and the South China Sea to the neighbourhood of Saigon before the close of the month. The lowest barometer readings were registered at about noon on the 25th, 28·50 inches at Magallanes, 4 miles from the centre, and 28·52 inches at Sorsogon, 3 miles from the centre. On the 22nd the rate of progress of the system was about 11 miles an hour; next day . . . it slowed down to only 3½ to 4 miles. Then after curving to WSW. it advanced at 12 miles until the morning of the 26th when the rate was again reduced to about 9½ miles during the passage across the South China Sea. . . . The area of destruction, while the storm was raging in or near south-eastern Luzon, was about 80 or 100 miles in diameter. . . . The wreck of the steamer *Quantico* took place on the evening of the 25th on the northern coast of Tablas Island; 21 lives were lost. . . . At Romblon, nearly all the houses, even those of strong materials, suffered. . . . Many big trees were uprooted. Light trees like bananas were completely destroyed. The tower of the church was blown down. There was no absolute calm (eye of the storm), but relative calm was observed for about one hour, with light winds, force 1 or 2.'

CHAPTER XXIV

SOUTH-WEST ASIA

(ASIA MINOR, SYRIA, PALESTINE, ARABIA, MESOPOTAMIA, PERSIA, AFGHANISTAN, BALUCHISTAN)

[INFORMATION on the general meteorology of this region will be found in Chapter xxvii, p. 168.]

In South-west Asia extreme continental conditions approach closely to the shores of the Mediterranean.

Winter is dominated by the great high-pressure system of Central Asia. Over the Mediterranean there are low pressures (p. 236), but their influence does not extend effectively more than some 20 miles from the coast; thus all the plateau of Asia Minor is covered by an extension of the Asiatic anticyclone, and another extension covers Arabia. Continental conditions prevail everywhere except on the littoral. The general winds are strong from the north-east, and the weather is cold and dry; but the low pressures over the Cyprus region and the Black Sea impose their own control on the surrounding coasts, causing the winds to be south on the north coast of Asia Minor, north on the south coast of Asia Minor, south and south-east in Palestine. Usually the Mediterranean cyclones do not advance far inland, but sometimes they are very vigorous and travel far to the east, assisted by the Caspian Sea and the Persian Gulf. An important track leads over the north of Mesopotamia, Persia, and Afghanistan into the plains of India, and the cyclones that follow it, all in the winter half-year, give those lands their chief supply of rain, which is nowhere very copious. In Afghanistan there is some, but less, rain in summer also, derived from the Indian monsoon; in North India winter gives only a secondary maximum in the rainfall curve, which is dominated by the summer monsoonal rains. The winter depressions cause unsettled weather, and their approach is indicated by southerly winds.

Over the Mediterranean and on the coasts these cyclones are the main weather control in winter and give the whole of the rainfall, which is moderate in amount, heavy only on some mountainous coasts, as on the south-east of the Black Sea. A local effect of importance is the warm indraft in front of them, the sirocco of Palestine and Syria, which occurs in all seasons except summer, but is specially important in spring when cyclones are vigorous, and the deserts of Arabia from which the winds are drawn are already at a high temperature. The winds that blow in front of the Black Sea depressions descend from the plateau of Asia Minor and are noticeably warm (föhn effect).

The whole region is liable to be swept by cold waves from the north in rear of deep and extensive depressions. The advance of the wave can often be traced clearly from its origin in Central Europe or Russia to the Black Sea, the Levant and adjoining lands, and far south in Egypt. Such cold waves naturally occur only in the cold months; they are especially severe when abnormally high pressures cover the Balkan Peninsula (WEICKMANN).

Another effect of the cyclones that pass eastward in spring along the S. coast of Asia Minor into Syria is seen in the frequent thunderstorms of the N. of Syria and Mesopotamia where the hot arid steppes meet the mountains on the SE. of Asia Minor which still bear their winter snows, so that there are strong temperature contrasts.

In summer the conditions are much simpler and more uniform. The main control is the great low-pressure system of south Asia, into which west and north-west winds blow from the Azores anticyclone. Cyclones are very rare, and the weather changes little from day to day. The coasts are cooler than the interior, since they receive prevailing on-shore winds, and the cooling influence is increased by the sea breeze which blows from about 8 a.m. till 6 p.m. with almost unbroken regularity.

The sky is almost cloudless, the sunshine intense, and the heat in the steppes and deserts very great, but thanks to the low humidity not in itself unhealthy. The wind blows strong especially by day, and its passage over the parched wastes often raises clouds of dust and sand; dust storms are not unknown even in winter. The N. coast of Asia Minor is peculiar in having E. and NE. winds westward of Cape Karembe, blowing through the windy Bosphorus. The SE. coasts of the Black Sea have strong on-shore winds, and get heavy rain in summer, though not so much as in winter.

Hence this region, excepting the coasts, has scanty rainfall, in winter owing to the dominance of the continental anticyclone, in summer owing to the winds blowing steadily, undisturbed by cyclones, from cooler to hotter regions. The winters are very cold, the summers very hot with intense sunshine, strong winds, and frequent dust storms. The land is mostly desert and steppe.

Asia Minor. Regions with very diverse climates are included in Asia Minor. The north coast will be described first, a well-watered tract, the mountains receiving much rain from the Black Sea cyclones in autumn and winter, and a considerable amount from the strong on-shore winds in spring and summer. Winter is a season of unsettled weather, as on the Mediterranean coasts; the southerly winds in front of cyclones are warmed by their descent from the plateau; the strong northerly ones in rear are often bitterly cold. The mean January temperature at Trebizond is 44° (cf. Marseilles, 43°). In summer there are north-west winds, constant save for the alternation between the stronger sea breeze by day and the land breeze at night; unlike most of South-west Asia the south-east coasts of the Black Sea have useful rain in the summer owing to the surrounding mountains. The summer temperature (mean for July at Trebizond, 74°) is much like that of the Mediterranean coasts of France and Italy, but the abundance of moisture produces a much more luxuriant vegetation. With the usual Mediterranean figs and olives there are tea gardens and plantations of Turkish tobacco. Partly owing to the shelter of the Caucasus Mountains this is a more favoured land than the coast between Sinope and the Bosphorus which is more open to cold NE. winds, and does not enjoy such frequent föhn winds from the plateau; the summers here are dry, and the vegetation has less than the usual Mediterranean luxuriance; the olive does not flourish.

From the north coast we make our way south through the forests of the coastal ranges on to the plateau which lies some 3,000–6,000 feet above the sea, enclosed by a mountain rim. The short journey brings us to an entirely different land, marked by continental extremes and scanty rainfall. The high pressures which cover the plateau in winter ward off the genial influence of the surrounding seas and give cold dry weather. The north-east wind blows strong, cold, and dry, though at times an unusually vigorous Black Sea cyclone may extend over the plateau, and south winds blow in front of it. But when the cyclone has moved east a cold wave sweeps down from the north behind it, often bringing snowstorms; at such times the weather on the bare open steppes is bitterly cold, and thousands of sheep may perish. On the higher plateau in the east, and in the deep valleys of the headwaters of the Euphrates, the winters are still more severe, and snow lies deep. At Sivas (4,400 feet) the mean temperature in January is 21°, and $-20°$ has been recorded; the July mean is 67°; the annual range, 46°, as well as the range from day to night, is high; the intense cold of winter is followed by hot summers, during which the aridity is only tempered by occasional thunderstorms. Spring is the rainiest season, but the great salt lakes bear witness to the aridity. The mean annual rainfall at Angora is 10 inches, at Sivas 14 inches; late summer is rainless.

Continuing our journey south we cross the Taurus, and descending to the coastal plain of Cilicia, we return to typical Mediterranean conditions. Owing to the southward exposure and the mountain shelter on the north the climate is very warm. Frost is rare and never severe. In summer the maximum temperature may exceed 110°. But the sea breeze which blows every day with great regularity especially in summer, setting in about 8 a.m., prevents excessive heat. The rainfall is about 20 to 25 inches a year, with a strong maximum in winter and spring. Where there are good irrigation facilities from the streams, as around Adalia and Adana, Mediterranean agriculture flourishes luxuriantly. The rich coastal strip is the more remarkable by contrast with the arid steppes of the interior, which are only a few miles distant (Zistler).

The west coast of Asia Minor has a similar climate, but the lowlands are wider, and are continued by wide valleys for some distance inland where the plateau itself is considerably lower than in the east. At Smyrna the mean January temperature is 46°, and in most years 6° or 7° of frost is recorded ; the mean for July is 81°, and it is rare for the maximum temperature to exceed 100°. The strong Etesian winds and the regular sea breeze during the heat of the day are useful in moderating the heat on the coast. In the sheltered valleys out of reach of the sea breeze the summer days are extremely hot and enervating.

Mesopotamia. The bold north-west–south-east feature lines exert a strong control on the wind directions. In winter the high pressures to the north give north-west winds, but frequent interruptions are caused by the passage eastward of depressions from the Cyprus region, in front of which the winds are south-east, with cloudy skies, some rain, and temperature much above the normal. The north-west winds are cold for the latitude and very dry, and they usually give clear, bright skies. The mean temperature in January is 40° at Mosul, 47° at Bagdad ; 0° has been recorded at Mosul, and once during a spell of nine days the temperature remained continuously below freezing-point, which shows that the winter cold may be severe in the north, at the foot of the snow-covered mountains of Kurdistan ; at Bagdad 10° has been registered. The cyclonic winds from the south-east bring all the rain that the land receives, but the total is less than 10 inches, and in lower Mesopotamia less than 5 inches ; practically none falls except in winter and spring, June to October being rainless ; much of the spring rain falls in thunderstorms. The rainfall is very variable from year to year. Round the Persian Gulf the south-east winds are called Kaus or Sharki ; they are sometimes followed for a few hours by a very strong wind from the south-west, called Suahili, which is dangerous for small craft.

In summer the prevailing winds are still north-west, blowing down the Mesopotamian corridor to the low-pressure system of Southern Asia ; they are called Shamal. Uninterrupted by cyclones they are remarkably constant, and especially strong during the day when they carry clouds of dust; there is a marked lull at night. The sky is cloudless, the air very dry, the sunshine fierce, and the heat intense. At Bagdad the mean July temperature is 94°, and 123° has been recorded; the maximum exceeds 100° practically every day in July and August. The heat would be still greater and less bearable but for the strong winds, Mesopotamia being more fortunate in this respect than north-west India, where the heat is more enervating owing to the calmer air, though the temperature is the same (NORMAND). In Mesopotamia the natives take refuge where possible in underground chambers during the day, and pass the nights on the house-tops in the comparatively cool breeze—but the mean lowest temperature on July nights at Bagdad is 80°. All the scanty steppe vegetation is burnt up, and the plains lie deep in fine dust which is swept up by the wind; the sky though cloudless is white rather than blue owing to this dust and the irregular refraction, and the visibility is often very poor not only over Mesopotamia but far out on the Persian Gulf. Sometimes 'dust devils' grow to great heights, one of 5,000 feet having been measured by an airman. The great rivers roll down in heavy flood from their mountain sources in March and April when the snows are melting rapidly and cyclones may cause heavy rains; the Tigris has risen 12 feet in a day in its lower course. The very great range of temperature is shown by the fact that the rapid Tigris has been known to freeze in winter at Mosul, where in summer 120° has been registered.

Persia. Mazanderan has a heavy rainfall, especially in winter, owing to the depressions over the Caspian and the influence of the Elburz Mountains, and the vegetation is luxuriant, including the orange, date-palm, sugar-cane, and cotton. The plateau has an even greater temperature range than Asia Minor; in spite of the altitude of 4,000 feet it is but little cooler in summer than Mesopotamia. The winters are cold, the mean January temperature being only a little above freezing-point, and readings below zero occur. The precipitation is insignificant except in the hills, and the land cannot be cultivated unless irrigation is possible. In the rainless summer there is hardly a cloud, and in the centre of the plateau the aridity is extreme, for even in winter there is practically no rain, and in the heat of summer violent winds carry clouds of salt dust over the irremediable desert.

Afghanistan and Baluchistan are similar to Persia, but the winters are less cold, the summers less hot, and the rainfall rather greater; in winter there is heavy snow on the mountains of north Afghanistan. The summer monsoon of India gives a secondary rainfall maximum in July.

Syria and Palestine. The coastal strip has a good Mediterranean climate, notable for its high autumn and winter temperature due to the warmth of the waters of the east Mediterranean; even slight frost is rare. The rainfall exceeds 20 inches except in the south of Palestine; it is over 36 inches at Beyrut; the rains normally begin in October, but are liable to be late; after April little rain falls, and the summers are rainless.

The plateaux of the interior overlook the coast. Owing to the altitude they have a heavier rainfall than the coast itself (Jerusalem 26 inches, Jaffa 21 inches), especially so in the Lebanon Mountains; but as the plateau descends eastward the rainfall diminishes rapidly towards the deserts of Syria and Arabia. As soon as the coast is left steppe conditions assert themselves more and more, the winters being cold and dry, frost frequent, and snow no rare visitant; the summers are very hot with frequent dust storms. The sea breeze sets in regularly every day on the coast. Especially in spring there are sirocco winds which bring dry dusty air and high temperatures from the deserts on the south-east.

Arabia. Most of the peninsula is desert, but the mountains of Yemen get heavy summer rain from the monsoon; Oman, being farther east and north, gets most of its scanty rain in winter. No details are available from the deserts of the interior, but the climate must resemble closely that of the eastern Sahara.

CHAPTER XXV

THE HEART OF ASIA

WITH a width of about 500 miles, narrower or wider as the enclosing mountains approach more or less closely, a vast arid tract extends for some 2,000 miles from the Pamirs, ENE. to the Khingan Mountains. It is really a great basin, or rather a series of basins, since it is enclosed on all sides, especially the west, by much higher ground; but the average elevation above the sea is about 3,000 feet, so that the term plateau is not inapplicable, especially as numerous mountain ranges intersect the region. The tops only of the ranges now project above the deserts of gravel and sand, the products of subaerial denudation which bury the lower parts of the mountains from which they were derived.

Central Asia is often classed as a continuation of the deserts of North Africa and Arabia. Though it resembles those regions in aridity, there are such great differences in the temperature conditions and also in the general causes underlying the climatic peculiarities that they ought to be considered separately.

In winter the heart of Asia is under the influence of the great cushion of dense air that collects over the cold continent, giving the highest atmospheric pressure (reduced to sea level) on the earth's surface. Calms and gently outflowing winds are the result in the central parts of the high-pressure region, and there can be no, or very little, precipitation. In spring the heated land throws off its burden of air, and the change to the low-pressure conditions of summer is a period of violent winds. In eastern Mongolia the north-west winds descend over China in great storms which carry much dust. In summer the low pressures draw in air from all sides, and under more advantageous conditions of relief a certain amount of rain would probably have been received, despite the fact that the sea is a thousand miles distant. But the deserts are surrounded by mountains, notably the Takla Makan, south-west of which tower some of the highest ranges on the globe. The Indian monsoon current is for the most part stopped by the wall of the Himalayas, a barrier five miles high. In the east a small portion of the monsoon makes its way into Tibet, but it must still cross the 700 miles of plateau, elevated 3 miles above sea level and ribbed by numerous ranges, before reaching the Takla Makan. Probably we may safely assert that none of the monsoon current reaches so far north as to make the descent into this inland basin, and even if it succeeded in doing so it would be so warmed by compression as to be a very dry wind. Similarly on the north and west the mountain barrier, though lower, suffices to ward off the winds from those quarters. Only in the east do moist winds penetrate, and we find a belt of good steppe land some 70 miles wide along the south-east border of the Gobi. The sea is only 350 miles away, and the south-east monsoon, when it crosses the Khingan, still contains enough moisture to make agriculture possible with the help of irrigation from the streams. The northern edge of Mongolia also is by no means desert, the rainfall being sufficient to maintain abundant grass in places. Urga has 7 inches of rain per year.

A very important factor in the meteorology is the high latitude. Central Asia lies between 37° and 50° N., and therefore there is a great seasonal change in the insolation. The annual range of temperature throughout these deserts is very great indeed.

It is instructive to recall for comparison the conditions of the Sahara. There the desert, far from being confined to the interior of the continent, reaches the sea on the west, north, and east, and mountains are of but minor importance in causing the lack of rain. Owing to the low latitude there is no excessive cold in winter, for even the north of the Sahara has a mean January temperature of 60°. As in almost all deserts the range of temperature is considerable, but not nearly so great as in Central Asia.

The rainfall is probably less than 2 inches a year in the deserts in the heart of Asia; in the east, as we have pointed out, the rainfall is somewhat greater and may amount to almost 10 inches in favoured localities. But even 2 inches must not be expected in the deserts every year. Many years have far less, and the balance is restored by a violent cloudburst at long intervals. Traces of the overwhelming floods that result may be seen in the deep channels, now dry, which the torrents excavated. There are no long series of records, but the available data show that the total precipitation is made up of winter snow as well as summer rain. The mean annual precipitation at Kashgar is 3·5 inches, of which over two-thirds fall in the summer half-year. At Yarkand half an inch was recorded in the single year a gauge was maintained. A traveller who stayed at Lukchun near Turfan for 10 months reports that it rained 5 or 6 times, and snowed 3 times, the snow disappearing the day after it fell. Urga has a mean annual total of 7 inches. No records of the amount of rain are available from eastern Mongolia, but the number of rainy days has been counted at Ha-kiao (lat. 41° N., long. 111° E.) for a few years, and the average found to be 59, 35 being in the summer half-year. This station, lying well to the north and west of the In-Shan and Khingan Mountains, is evidently reached by the south-east monsoon of China.

The air is dry. Sven Hedin recorded a mean relative humidity of 28 per cent. in the Takla Makan in May, 69 per cent. in December. The mean summer humidity at Lukchun at 1 p.m. was 20 per cent. The sky seems to be somewhat more cloudy than in the Sahara.

The summers are very hot, with the sun glaring down during the long days through the dry air. Satisfactory records are wanting; the best available are given below:

Station.	*No. of Years' Record.*	*Altitude in Feet.*	*Mean Temp. for July.*	*Highest Temp. recorded in July.*
			°F.	°F.
Kashgar	2	4,255	80	—
Yarkand	1	4,120	82	103
Uliassutai	1½	5,365	65	94
Urga	7	3,445	63	97
Lukchun	2	−100	90	118

Uliassutai and Urga are comparatively cool owing to their higher latitude; the position of Lukchun below sea level explains its excessive heat. But the Lukchun figures are eclipsed by the reports of Turfan, near which the depression sinks to 300 feet below sea level. Domestic animals, even camels, cannot live through the summer heat, and have to be driven up the mountains. Ellsworth Huntington tells us that 'according to the Chinese, the summer is so hot that during the day the birds all gather in the shade of the trees beside the rivers. If one of them flies up, he is scorched to a cinder and falls sizzling into the water. Another Chinese yarn affirms that the heat is so great that after blowing on your rice to cool it, you must ply your chopsticks as fast as possible. If you do not, the rice will become hot again and burn you!' During the heat of the day the natives retire to underground chambers. Younghusband, speaking of a journey between the Tian Shan and the Altai, says: 'The heat was intense, for the wind blew off the heated gravel as from a furnace, and I used to hold up my hand to protect my face from it in the same way as one would in front of a fire.' Other travellers speak of the sand being hot enough to burn the feet even through thin shoes.

In summer the temperature of Central Asia is not very different from that of the Sahara, but in winter there is a great contrast (Fig. 62). Frost is indeed by no means unknown throughout the Sahara on winter nights, but the mean January temperature is everywhere above 50°. In the deserts of Central Asia, the mean for the same month is considerably below freezing-point. Standing water and small rivers are frozen right across throughout the winter months and the natives bring home their water supply in the form of blocks of ice. It is rare for the thermometer to rise above freezing-point even at midday ; at Tarim Jangiköl, 2,890 feet above the sea, Sven Hedin found that the average maximum daily temperature, during the January he stayed there, was as low as 26°. The mean January temperature was 9°, and the lowest reading he recorded during his winter's stay was −14°. In the middle of the Takla Makan he recorded a minimum of −25° in the beginning of January. On January 2, the maximum temperature was only 8°. Other records are :

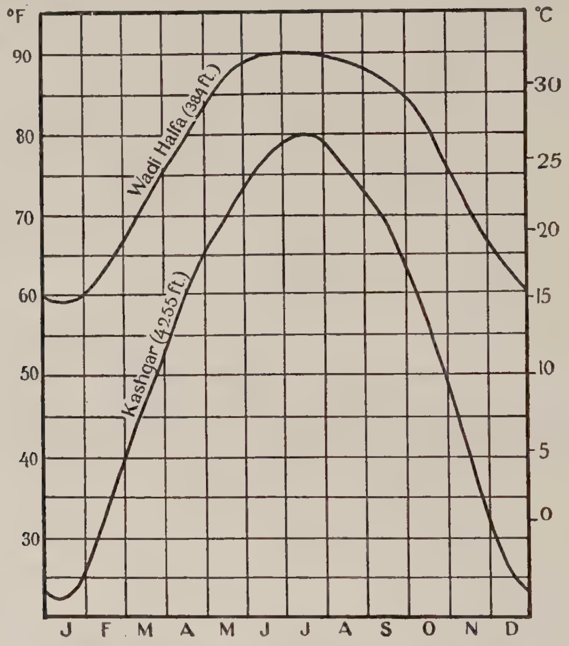


FIG. 62. Mean temperature curves for Wadi Halfa and Kashgar.

Station.	*No. of Years' record.*	*Altitude in Feet.*	*January.*	
			Mean Temp. °F.	*Lowest Temp. recorded.* °F.
Kashgar	3	4,255	22	—
Yarkand	1	4,120	21	2
Uliassutai	1½	5,365	−15	−40
Urga	7	3,445	−15	−46
Lukchun	2	−100	13	−5

The dryness and stillness of the air make these low temperatures more endurable than might have been expected. Ellsworth Huntington says he could sleep comfortably under a sheepskin in the open air, with a temperature of −6°.

In general, the cold winter lasts from the end of November till the end of March. The west of the Tarim Basin has 3 months, Urga 6 months, with a mean temperature below freezing-point. The transition to summer is accomplished by May, so that spring is a time of extraordinarily rapid increase in temperature. At Tarim Jangiköl the mean temperature when Sven Hedin was there was 17° in February, 40° in March, 55° in April, 69° in May. The difference between February and March was greater than that between January and July in England.

The daily range of temperature is very great throughout the year, about 36° near the Tarim; 24° at Lukchun in winter, 30° in summer. The annual range reaches remarkable figures, 60° at Kashgar, 77° at Lukchun, 79° at Urga, and 80° at Uliassutai.

Early in spring violent ENE. winds set in, to continue by day till the end of summer. Blowing with gale force they carry with them clouds of dust swept up from the desert, which darken the air and make life miserable. They are known as Karaburan, i. e. ‘ black storms ’. The sand they drive along is one important cause of the rapid changes in the courses of the rivers through the desert. ‘ The daily winds (in the Gobi) were often extremely disagreeable. It was with the greatest difficulty that we could keep our tents from being blown down, and everything used to become impregnated with the sand, which found its way everywhere, and occasionally we had to give up our march because the camels could not make any head against the violence of the wind.’ (Younghusband.) The coarse particles of gritty sand are not carried beyond the limits of the desert, but the lighter particles are blown far outside, and give a characteristic hazy appearance which is very common on summer days. The fine dust gradually sinks to the ground and forms loess. Ellsworth Huntington describes the scenery on the mountain slopes about 14,000 feet above the sea on the south-west of the Tarim basin, as follows: 'Instead of the boulders and rough hollows which one usually sees in moraines, these presented surprisingly soft outlines, for they had been deeply buried in loess deposited from the atmosphere. The loess was covered with thick grass, full, as we soon saw, of countless Alpine flowers and dotted with sleek flocks of sheep and herds of cattle. . . . Our gaze went out far beyond (the lower mountains) to where the last low hills gave place to a strange yellow band. It seemed at first to be the sandy desert of the heart of Asia; but during the two hours of our stay on the pass it expanded and rose, and we then knew it for the inevitable dust-haze which shrouds the country more than half the year.' The dust storms rage by day only. At night the desert air is usually calm. To quote again from Younghusband's narrative: 'The nights were often extremely beautiful, for the stars shone out with a magnificence I have never seen equalled even in the heights of the Himalayas. Venus was a resplendent object and it guided us over many a mile of that desert. The milky way, too, was so bright that it looked like a bright phosphorescent cloud, or a light cloud with the moon behind it. This clearness of the atmosphere was probably due to its being so remarkably dry. Everything became parched up and so charged with electricity that in opening out a sheepskin coat or a blanket, a loud cracking noise would be given out, accompanied by a sheet of fire. The temperature used to vary very considerably. Frosts continued to the end of May, but the days were often very hot, and were frequently hottest at nine or ten in the morning, for later on a strong wind would usually spring up, blowing sometimes with extreme violence till sunset.' Autumn and winter are free from dust storms, and the clear, dry, invigorating air and pleasant temperature of the second half of September, October, and the beginning of November are described as forming an ideal climate.

Ellsworth Huntington describes the conditions of agriculture in this arid land. The Takla Makan desert is surrounded by a ring of coarse gravel detritus which has been carried down from the mountains by the streams in their rapid course to the depression. The water of the smaller streams disappears rapidly into and percolates through the gravel, and comes to light again at a lower level when it meets with finer deposits of sand and clay, and here there is a fairly continuous zone of moisture and verdure. In the most favoured districts, where the water is abundant enough to fill irrigation channels, there are gardens of unrivalled luxuriance which produce the most luscious fruits, pears, apricots, grapes, melons, &c. Agriculture depends for its moisture in west Mongolia entirely, and in east Mongolia largely, on the water that seeps through in this way, or on the running streams from the mountains, whose short courses across the desert are made still shorter by the demands of irrigation. Evaporation everywhere greatly exceeds precipitation, and most of the streams, which owed their origin to the rains and melting glaciers of the distant mountains, soon wither away in saline lakes. A belt of trees, reeds, and other undergrowth marks their course. The Tarim, Khotan Daria, and Cherchen Daria alone succeed in extending their ribbon of verdure right across the desert.

The mountains round the Tarim basin have of course more abundant precipitation than the floor of the depression. It is estimated at 25 to 30 inches a year. The higher summits have perpetual snow, and small glaciers. Unfortunately, though there is sufficient moisture the mountain tops are too rugged, and the cold too intense, for even nomads to pasture their herds on them. But the zone between 10,000 and 14,000 feet has excellent pasture which is grazed by the herds of the Kirghiz. Below 10,000 feet scantiness of moisture begins to take effect and at 5,000 feet we are in the desert. According to Sewerzows, the Khirgiz of the Thian Shan pasture their flocks in winter above 10,000 feet in order to keep above the zone of heaviest snowfall, which is also the zone of forest. Above 10,000 feet the snowfall in winter becomes less (inversion of rainfall); but it is not so with the summer rainfall, for in summer, owing to the higher temperature, inversion of rainfall begins considerably higher. Hence the zone between 10,000 and 14,000 feet receives abundant summer rain to make rich pasture, which remains largely free of snow in winter.

From the Pamirs 10 years' meteorological observations are available, taken at Pamirski Post, a Russian station on the Murghab River, 12,000 feet above the sea. The precipitation is remarkably low, only 2 inches a year (compare Leh in the Indus valley); probably the amount is somewhat greater at less elevations, for there is said to be much snow in the lower valleys; the mountain ridges get but little snow, and have no glaciers. Pamirski Post has the steppe régime of rainfall, the rainiest season being late spring and early summer. The air is remarkably dry, with a mean relative humidity of 41 per cent. in summer, 59 per cent. in winter, and clear except when hazy with dust. The rays of the sun are very powerful even in winter, when the shade temperature is far below freezing-point. The difference between day and night temperature is very great. The mean temperature in January is −1°, in July 57°; the extreme readings ever recorded were −52° and 82°. Very strong south-west winds blow up the valleys by day throughout the year.

CHAPTER XXVI

TIBET

Not only the climate, but the whole geography of Tibet is essentially conditioned by the great elevation. The plateau is an enormous block, elevated more than 12,000 feet above the sea, except in the valley bottoms of the east. Its length is about 1,200 miles, the width 400 miles in the west, and 700 miles in the east. It is buttressed on the south by the Himalayas, on the north by the Kuen Lun, the Altyn Tagh, and the Nan Shan. On this plateau the atmospheric pressure is only about half, in the highest parts rather less than half, that at sea level, and visitors suffer greatly from fatigue, shortness of breath, and mountain sickness, as the result of any undue exertion in such rarefied air.

The north-west is known as the Chang (1 in Fig. 63). Here the altitude is greatest, over 15,000 feet everywhere, and on the average 15,000 to 17,000 feet, that is to say considerably greater than that of Mount Blanc. The region consists of a series of wide open flat-bottomed detritus-filled valleys with a general east–west direction, separated by more or less parallel ridges. The climate is very rigorous, and hence the vegetation is scanty. Very much of the surface is bare rock or soil, parts are covered not with vegetation but with salt, which glistens so white in the intense sunshine that the natives who have to cross it wear dark spectacles. But many parts have a fairly good plant covering, consisting chiefly of grasses and other low plants rarely more than 3 inches high, and notable for their great root development, a sign that they find the habitat a very dry one. Wild animals, such as antelopes, feed on the grass, but even the hardy nomads never take their flocks to these bleak uplands. There are, of course, no trees or shrubs, but it is interesting that flowering shrubs have been found elsewhere in Tibet as high as 19,000 feet, and butterflies as high as 17,600 feet.

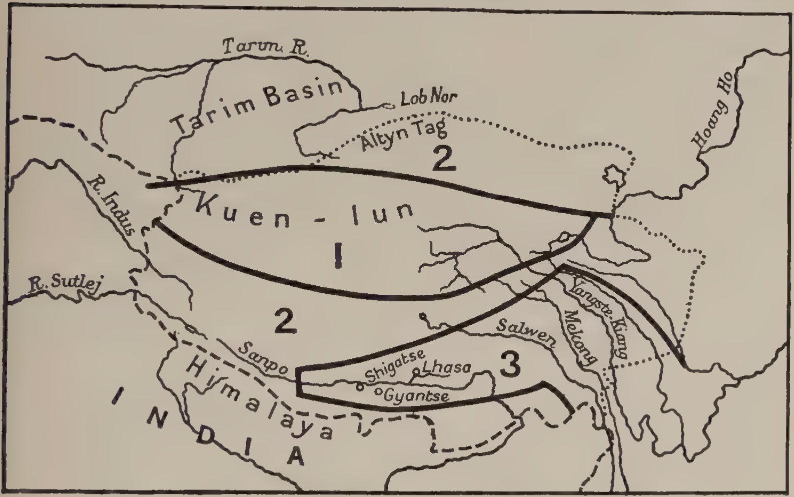


FIG. 63. The main climate regions of Tibet. (Waddell).

South of the Chang is the belt of ‘ Upland Pastures ’ (13,000 to 15,000 feet), the summer resort of the Dokpa and their herds (2 in Fig. 63). There is abundance of excellent grass here.

The great valleys in the south, of the Upper Indus and the Sanpo, and in the south-east, of the Yangste, Mekong, and Salwen, form the third division, the most important economically (3 in Fig. 63). The south-east of this region is remarkably fertile.

Trees flourish up to 13,500 feet above the sea in parts, and travellers have been much impressed by the luxuriance of the valley forests of the east of Tibet at altitudes of 12,500 feet. Wheat is grown as high as 12,500 feet, though it cannot be depended on to ripen above 11,500 feet. Millet, maize, and rape are common crops. Some of the alluvial valley-bottoms are extremely productive, in particular that of the Lhassa River has been specially commented upon by the few foreigners who have had the privilege of seeing it. It has the advantage of an extensive system of artificial irrigation.

These general statements on altitude and vegetation probably give the most useful indication possible of the climate, since there are no reliable temperature and rainfall statistics established by long-continued observations. The only readings are those of travellers, taken on their journeys or during a few months' halt. Hence the mean values mentioned in the following paragraphs are not founded on very satisfactory data, and must be regarded as merely giving a general idea of the heat and rainfall.

The warmest month in the north-west of Tibet is August, but even then frost must be expected every night. The lowest reading recorded in this month is 19°. The air is remarkably clear, containing very few dust or moisture particles, and the barometer stands at about 16 to 17 inches. Consequently insolation is very intense, but the air in the shade is cold. Sven Hedin recorded 147° on a black bulb thermometer (sun temperature) when the ordinary air (shade) temperature was 54° to 61°; the barometer reading was 17·1 inches. The range of temperature between day and night is very great. Winter is exceedingly harsh. Bonvalot traversed the country during the months December to March, and noted a temperature as low as −40° F. on January 6. The lowest reading recorded by Sven Hedin was −40°, at about 35° N. lat., 80° E. long. On the previous day he tells us 'the night came down over the enormous snowfields, biting cold. The temperature went down to the freezing-point of mercury (−37°). I had two candles and a nice fire in my tent as it was Christmas Eve. The next morning one pony lay dead and hard on his place among the rest.'

We must now consider the conditions in the milder south-east. The mean daily maximum temperature at Lhassa (11,600 feet) is

72° in June, 71° in July, 64° in August. The slight drop in July, and larger drop in August, are presumably due, in part at any rate, to the cloudy skies of the monsoon. The highest maximum recorded out of doors in the shade is 77°. Probably it never freezes in August.

Everywhere in Tibet spring is much delayed since there can be no very great rise in temperature till the snow covering is melted. In the agricultural districts the melting is artificially hastened by scattering stones and earth on the snow to absorb the sun's heat. Seed cannot be sown till April. Autumn is early, and in the central districts all the crops must be gathered by the middle of September, for night frosts then become very severe even as low as 12,000 feet above the sea. In November the smaller lakes freeze over; Tengri-Nor becomes a sheet of ice early in December. Even geysers are turned into pillars of ice in the depth of winter. The numerous very salt lakes, however, do not freeze. All the rivers are frozen solid except those in the south-east, which are at a less altitude, and have a greater volume. The Lhassa River has only a fringe of thin ice. Kuku Nor, though salt, is often frozen in winter, and devout Buddhists walk over the ice to the holy island of Kiusu. A Russian expedition made meteorological observations for fifteen months in the south-east of the Tsaidam salt steppe region, lat. 36·2° N., long. 97·3° E., at an altitude of 9,380 feet. The mean temperature was 9° in January, 63° in August; the extremes recorded were −20° and 91°.

With regard to the question of the amount and season of precipitation, we are at once confronted with the problem, how far Tibet is influenced by the summer monsoon. The Himalayas undoubtedly form an effective climate barrier. In the west, probably hardly any of the moist monsoon air current is able to cross it, for the mountain wall is very high and continuous, and, moreover, the barometric gradient directs the winds along rather than across the mountains. But in the east the mountains are lower, and the deep and fairly open valleys of the head waters of the great rivers of Further India and southern China, offer a ready ingress to the moist winds. Hence there is summer rainfall of true monsoonal origin in south-east Tibet, July and August being the rainy months. The mean annual rainfall is estimated at from 10 to 20 inches at Lhassa and Shigatse. In the west most of the precipitation seems to fall in winter, of course in the form of snow, and is doubtless associated with the winter cyclones of north-west India and the western Himalayas. Sven Hedin's opinion is that in winter there is more snow in west than in east Tibet, in summer more rain in the east than in the west.

The monsoon currents that succeed in passing the Himalayas find another barrier in the Tangla Mountains, which run from WNW. to ESE. through the centre of Tibet, attaining altitudes of over 25,000 feet, where they seem to be finally stopped. North of the Tangla the annual precipitation is probably not over 4 or 5 inches; Leh, the nearest comparable station with good records, has 3 inches. Travellers have suffered severely from lack of fresh water in crossing the stony barren wastes on the north. But as soon as they cross the Tangla Mountains towards the south, they find in summer cloudy skies and only too much rain—monsoonal conditions. Probably the rain is frequent rather than abundant.

Violent and constant winds are frequently noted in travellers' diaries. They blow especially by day all the year on the higher plateaux, and make the low temperatures harder to bear than the thermometer reading would suggest. They often bring blizzards of snow even in summer time. They usually blow from the west, except during the monsoon in the south-east. Probably they represent the currents in the upper layers of the atmosphere flowing in towards Central Asia in winter, feeding the high-pressure system shown by the sea-level isobars, and the out-flowing surface winds of the winter monsoon of south-east Asia.

The small precipitation is doubtless the chief reason that the snow line is so high in Tibet. On the south face of the Himalayas it is as low as 16,000 feet, but in Tibet it is probably 19,000 to 20,000 feet. Other factors combining with the small precipitation are the strong winds, rapid evaporation, and intense sunshine.

CHAPTER XXVII

THE RUSSIAN EMPIRE

[The term 'Russian Empire' is used with the meaning it bore before 1917.]

With Russia in Asia we include Russia in Europe as belonging, from our point of view, rather to Asia than to Europe. Europe may be said to be a peninsula of Asia, and we might regard European Russia as the root of the peninsula. It may conveniently be treated with Siberia, for the Ural Mountains form no important climate divide. As we travel east through France and Germany from the western sea board of Europe, washed by the warm and stormy waters of the North Atlantic, we experience a gradual transition, which, it is true, continues right into the heart of Siberia; but at the Vistula we reach a climate which is definitely continental. That river forms a convenient if arbitrary boundary between the ocean-controlled climates of Western and Central Europe and the essentially continental type to which practically all the Russian Empire conforms.

The Russian Empire is an enormous unbroken land mass with an area of eight and a half million square miles. Being situated in middle and high latitudes it has a very extreme climate. In Eastern Siberia is situated the 'cold pole' of the earth, where the winters are the coldest known and the range of temperature greatest. Thus we have here a most interesting study in continental extremes. Canada is the only land which is at all comparable. In the southern hemisphere the land masses in similar latitudes are attenuated, and consequently the winters are mild.

The region contains vast plains not much above sea level, and therefore our isotherm maps give a closer approximation to actual observed temperatures than in the case of many countries, where a considerable correction to sea level has been applied. The most important elevations are the Caucasus and the mountains of Armenia; and the lesser heights of the Urals, the Yaila Mountains, and the mountains of south and east Siberia. The maps on which this chapter is based are those in the

Russian Climatological Atlas, which contain newer and more extensive climatic data than can be found elsewhere.

Pressure conditions. In January (Fig. 31), the dry cold of Central Asia so intensifies the subtropical high-pressure belt that we find the greatest high-pressure area known at any season on the earth. Lukchun (57 feet below sea level), near its centre, has a mean pressure in January of 30·8 inches. The normal high-pressure belt is not only intensified but drawn far north, since the greatest cold is in the north of the continent. We may contrast the summer conditions when the centre of lowest pressure is in the south. Towards the west there is a well-marked extension of the high pressures along lat. 50° N., across southern Russia and Central Europe to the Atlantic, forming the barometric ' backbone ' of Europe. This ' backbone ' forms a most important wind divide. North of it, over all northern and central Russia and Siberia, the prevailing winds are from the south and west; west of the River Obi they belong to the Icelandic low-pressure system of north-west Europe. Variable winds mark the high-pressure axis; south of it, in the steppes of south Russia and Turan, are north, north-east, and east winds, very cold and dry. West and central Siberia has in general southerly winds, exceeding cold; in the east of Asia the winter monsoon blows from the north-west. In April and October the general pressure distribution and hence the prevailing winds are similar to those of January. The absolute pressure in the centre of the continent is considerably less, and the surrounding gradient is not so steep, but we find the same high-pressure ridge along 50° N. separating south Russia, with north-east winds, from central and north Russia and Siberia, with south and west winds. Indeed, these features, with relatively high pressure over Central Asia, persist from August to April, a period of nine months.

The feature of the summer conditions (July, Fig. 31), which last for only three months, is the deep trough of low pressure over the south of Asia, with its centre in Afghanistan. A vast extension towards the north-east covers Central and North Asia as a shallow depression surrounded by gentle gradients; the mean July pressure at Lukchun, 57 feet below sea level, is 29·6 inches, 1·2 inches less than in January. The North Atlantic anticyclone, now much intensified, projects far over Central Europe, and can perhaps be recognized as far as Lake Baikal in the curve of the 29·7 isobar, so that there is a tongue of high pressure as in winter, but it points now towards the east. North and central Russia has westerly and north-westerly winds, south Russia north-westerly in the west and north and north-easterly in the east, which continue as the north-east trades of the Mediterranean. Turan has steady north winds, except Ferghana and other valleys in the mountains, where the wind blows up the valleys, from the west in the case of Ferghana; the north of Siberia has east winds and in Eastern Asia the south-east monsoon is blowing. Round the Caspian Sea there is a seasonal reversal of wind direction, the air flowing in winter from the dry cold land to the relatively warm sea, and in summer out from the relatively cool sea to the hot land (Fig. 64).

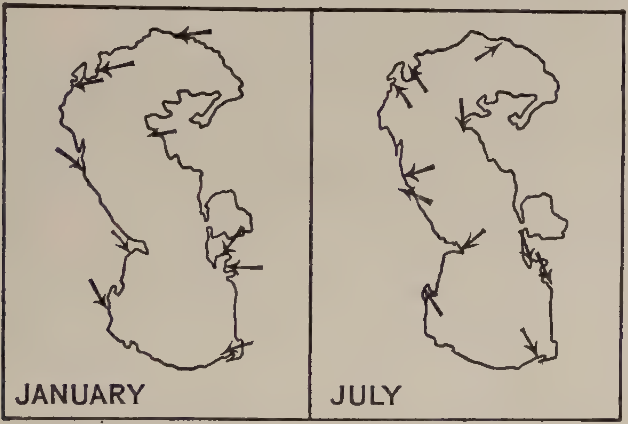


Fig. 64. The prevailing winds around the Caspian Sea.

Temperature (Fig. 30). In winter the warm Atlantic Drift is a more important source of heat for Russia than direct insolation. The prevailing westerly winds of the north and centre of the country carry the oceanic influence far inland. In the south, on the other hand, the prevailing north-east winds are cold, since they originate in the heart of the continent. Consequently the isotherms have a general north-west to south-east trend in European Russia and west and central Siberia. Every mile we advance towards the north-east, the colder it becomes, the temperature decreasing with remarkable uniformity right into the north-east of Siberia where at Verkhoyansk we find the most extreme winter known anywhere, not excepting the Polar regions. The heat of the North Atlantic is more than 3,000 miles distant beyond the frozen continent; the Pacific Ocean has not much effect, since the wind blows off-shore almost continuously, and, moreover, ranges of hills intervene; the Arctic being ice-covered, cannot ameliorate the harsh conditions to any great extent. The warm Indian Ocean lies far to the south of the insuperable barrier presented by the lofty mountain ranges and wide deserts of the centre of Asia. Of direct insolation there is none at the winter solstice, for Verkhoyansk is within the Polar Circle. During the long winter nights radiation goes on rapidly from the snow-covered ground through the clear calm dry atmosphere and the cold air stagnates in the valley-bottoms. The mean temperature in January at Verkhoyansk is −59°, the average lowest temperature of the month −83°; −90° was recorded in February 1892, this being the lowest reading ever taken on the surface of the earth. The highest temperature ever recorded in January was −13°. The winter cold is less intense towards the north. Sagastyr (on the Arctic Ocean, delta of the Lena) is about 25° warmer in January. This is due, according to Woeikof, not so much to the influence of the ocean, which is ice-covered for some hundreds of miles from the shore, as to the stronger winds on the flat and treeless tundra, and the absence of temperature inversion. The fact that the cold pole is so far east in Siberia is an indication of the relative importance of the Atlantic and Pacific Oceans in determining the winter climate of Eurasia. The prevailing westerly winds, unimpeded by any important mountain barrier, bring heat for hundreds of miles inland from the Atlantic; the moisture they contain is also effective to the same end by checking radiation.

The theoretical probability that the low winter readings of eastern Siberia are due to drainage of cold air into the valley-bottoms, in which all the regular meteorological observations are made, and that inversion of temperature is the normal winter condition, is strengthened by the few records available from elevated stations, which are shown to be considerably warmer. The isotherms drawn on our maps represent only the conditions of the valley-bottoms.

It is important to notice that almost the whole of the Russian

Empire has a mean January temperature below freezing-point. The isotherm of 32° F. bisects the Crimea and the Caspian Sea, and follows roughly the line of the Trans-Caspian Railway across Turan, so that only the south of the Crimea, the lower ground of Trans-Caucasia, the southern half of the Caspian, and the extreme south of Turan have a mean temperature in January above freezing-point. And even south of the 32° isotherm there is a considerable area in Georgia which forms an 'island' of cold, with mean January temperature far below freezing-point even when corrected to sea level; thus at Kars, 5,740 feet above the sea, the January mean is 7°. In Trans-Caspia much of the land lying south of the 32° isotherm is mountainous, and hence has actual temperatures much lower than the isotherms show. To appreciate the significance of the January isotherms for the life of the Russians we must remember that almost all the vast area to the north and east of the 32° line is snow-covered for some weeks at least every winter, the sledge is the usual conveyance, and the rivers are frozen. The 14° isotherm crosses European Russia obliquely from the north of the Gulf of Bothnia, through Moscow to near Astrakan. The north-east shores of the Caspian Sea are on the cold side of it, and hence, although the latitude is 47° N., the winters are colder than at Petrograd in lat. 60° N. Practically all Siberia has a January temperature below 0° with the exception of the south of the Pacific coastal strip, but even at Vladivostok the mean is only 5°.

The warming influence of seas and lakes on their neighbourhood is clearly marked in winter. Mariehamn, on the Åland Islands in the Baltic, has a mean January temperature of 27°, but at Petrograd, 350 miles east at the head of the Gulf of Finland, which, however, is frozen over, the mean is only 15°. The White Sea and the Peninsula of Kola form another excellent example; as we go north along the meridian of 35° E. the temperature actually rises over the White Sea, to fall over Kola and rise again on the Murman coast. It is worthy of notice that the coldest part of the north-west of Russia is well to the west under the lee of the Scandinavian highlands; this is an exception to the usual increase of temperature in the direction of the Ocean; the explanation perhaps lies in the barrier opposed by the highlands to the warm moist winds.

Proximity to the sea and the shelter of the Yaila Mountains combine to give the south of the Crimea, the Russian Riviera, its mild winters. At Yalta the mean January temperature is 38°, and the lowest reading on record 9° ; at Ekaterinoslav, 280 miles north, fully exposed to the cold north-east winds that sweep over the steppes, the corresponding figures are 19° and −31°. Even Yalta is considerably colder than the north coasts of the Mediterranean Sea, which, however, are in slightly lower latitudes. The coast of the Black Sea at the foot of the Caucasus Mountains is another climatic oasis, thanks to the mountain shelter, a shelter which is said to be effective even on the south coast of the Black Sea. When, however, a deep depression lies over the eastern part of the sea, the lower eastern end of the Caucasus is unable to keep back the inflow from the north-east, which sweeps down as the dreaded Bora, an exceedingly strong, cold, dry wind from the steppes, known especially in the neighbourhood of Novorossiisk.

The isotherms curve northward over the south of the Caspian Sea, the northern part of which, however, being frozen, has little or no modifying influence. The Arctic Ocean warms the north of Siberia somewhat, but its frozen surface is not so effective a source of heat as the open Pacific, on the shores of which the isotherms are closely crowded. The most striking effect is provided by Lake Baikal in December (Fig. 65) when the water is freezing but not yet frozen over ; the course of the isotherms shows the combined effect of the open water and of the liberation of latent heat during freezing ; there is much fog on the shores of the lake at this time. In the second half of the winter the lake is completely ice-covered and has much less warming influence. The Sea of Aral, being shallow, freezes over rapidly in the beginning of winter, and thenceforward does not appreciably warm its neighbourhood.

To consider next the lowest readings that have been recorded, we have seen that the warmest part of the Empire is the south-west, the coasts of the Black Sea and the southern half of the Caspian, but even here there are few stations where the thermometer has not been known to fall below 18°. The south of Turan has lower records, −15° at Merv, −24° at Nukuss, on the delta of the Amu-daria. The whole of the north-eastern half of European

Russia, including the coast of the Arctic Ocean; and all Siberia has experienced temperatures below −40°, all Central Siberia below −60°, and Verkhoyansk has known the extreme figure of −90°.

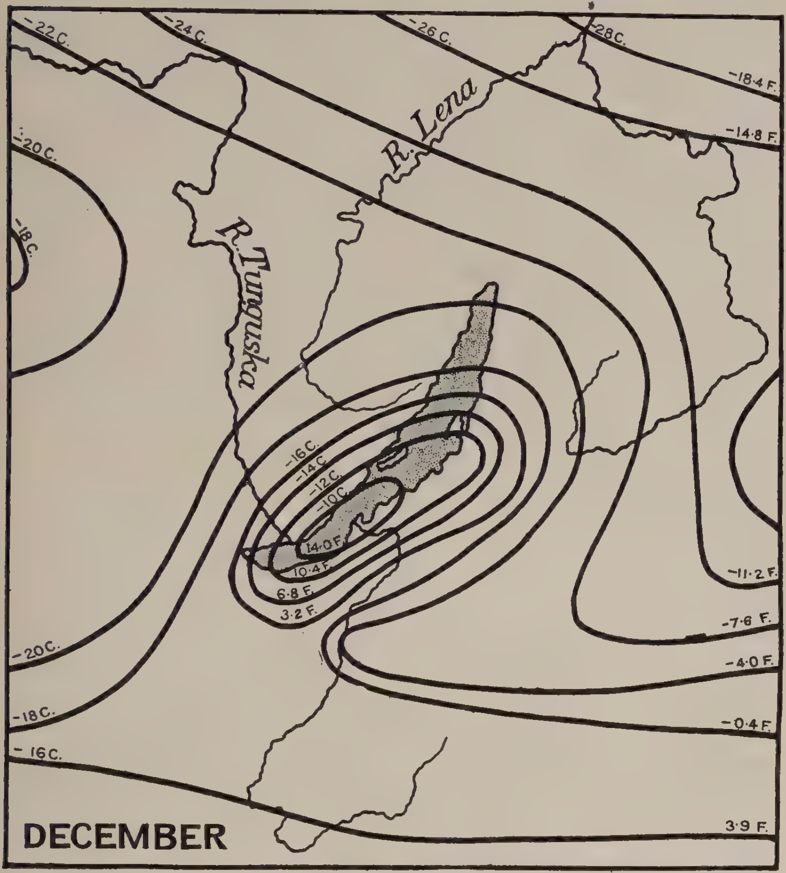

-22 C.
-24 C.
-26 C.
-28 C.
-18·4 F.
-14·8 F.
R. Lena
-20 C.
-18 C.
R. Tunguska
-16 C.
-14 C
-12 C.
-10 C.
14·0 F.
10·4 F.
6·8 F.
3·2 F.
-11·2 F.
-7·6 F.
-4·0 F.
-20 C.
-18 C.
-0·4 F.
- 16 C.
3·9 F.
DECEMBER

Fig. 65. Mean temperature in the neighbourhood of Lake Baikal in December. Compare Fig. 66.

The Siberian winter is by no means so unpleasant as these low temperatures might suggest. The air in the interior of the continent is remarkably bracing and often calm, so that it is easy to protect oneself adequately with furs. Vegetation hibernates, and flourishes luxuriantly again in the summer warmth. ‘The inhabitants of the south of East Siberia have no cause to envy the winters of Central Europe with their leaden skies, strong damp winds and sudden changes of temperature, which are felt the more because they oscillate about freezing-point. Except on the coasts the sky is beautifully clear, especially between September and April, and of a deep violet-blue which recalls Italy and north India. The air is transparent and calm, and the bright sunshine is so warm that the snow on the roofs melts though the air temperature is below 0°.' (WOEIKOF.) It is only when the wild Buran blows, the Purga of the tundras, that there is danger to man and beast. During these storms the wind sweeps with extraordinary violence over the open plains. The air is thick with snow, descending from the sky, and swept up from the ground, so that it is impossible to see. Though the temperature is not remarkably low the cold is felt keenly, and any one who is overtaken runs a serious risk of losing his way and being frozen to death. The Buran is known and dreaded in south Russia and throughout Siberia, except in the forests. It often makes it impossible to cross the passes of the Stanovoi Mountains for weeks together in winter.

The air is usually described as very dry; it is said that in winter clothes may be dried by leaving them lying on the snow even at a temperature of −40°. We may be inclined to challenge this statement when we find that the mean relative humidity in January is, according to the *Russian Climatological Atlas*, over 80 per cent. almost everywhere, and over 85 per cent. in European Russia, figures almost identical with those for England, where the air is notably humid. But we must remember that in Russia the air is very cold, and hence, though the relative humidity is high, the absolute humidity is very low. On coming into contact with the human body the air is very much warmed, and its relative humidity falls to a much lower percentage than that of the air in England, raised to the same temperature. Physiologically, therefore, the Siberian winter air is 'dry'. A few figures will make this point clearer. At Oxford, England, the mean relative humidity of the air in January is 87 per cent. and the mean air temperature is 39°; when this air is heated to 60° (we choose this figure arbitrarily as an approximation to the temperature to which air is heated near the body) the relative humidity becomes 42 per cent. At Tobolsk the mean relative humidity in January is the same as at Oxford, 87 per cent., the mean air temperature is −2°, and if the air is heated to 60°, the relative humidity falls to 8 per cent., about a fifth of the figure for Oxford.

In summer the land mass is warmer than the sea. The July isotherms follow the parallels of latitude more closely than those of January, except along the Baltic and Pacific coasts; their general trend is WSW. to ENE. The 50° isotherm, the southern boundary of the tundra, cuts off the northern peninsulas. The 70° line crosses central Russia and southern Siberia. The highest temperatures occur in the deserts of the south, the south of Turan having a July mean over 86°. The effect of bodies

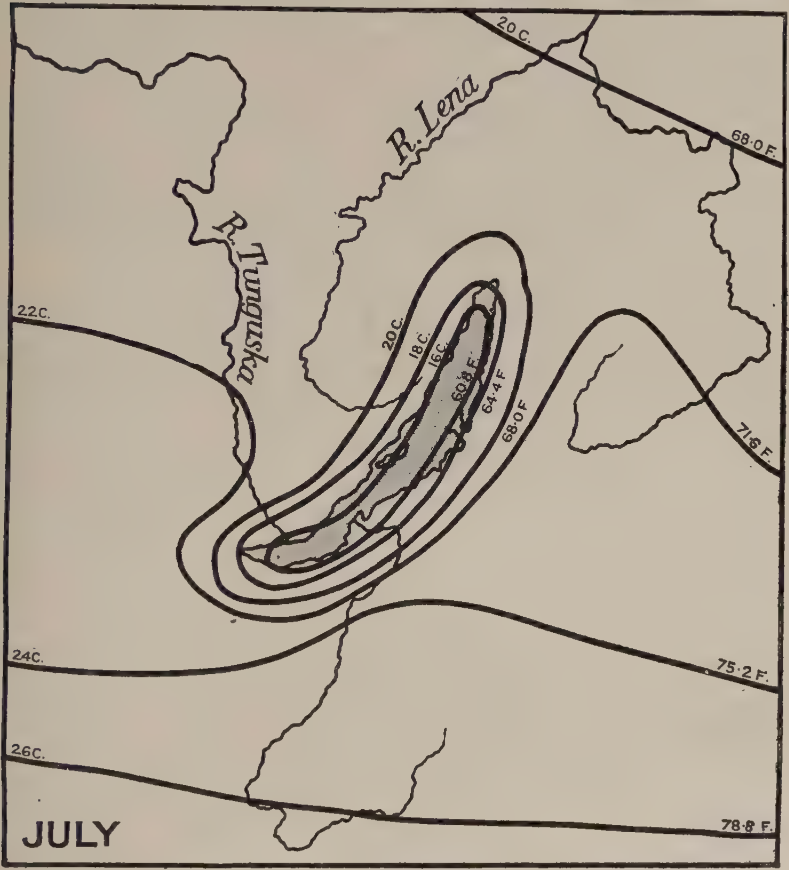

20 C.
68·0 F.
R. Lena
R. Tunguska
22C.
20C.
18C.
16C.
60·8 F.
64·4 F
68·0 F
71·6 F.
24C.
75·2 F.
26C.
78·8 F.
JULY

FIG. 66. Mean temperature in neighbourhood of Lake Baikal in July. Compare Fig. 65.

of water is considerable though not nearly so great as in winter. At Mariehamn (Åland Islands) the mean July temperature is 59°, and the absolute maximum 85°; at Petrograd the corresponding figures are 64° and 97°. The insular station is the cooler in summer as it was the warmer in winter. The interior of the Kola Peninsula is somewhat warmer than the coasts. The isotherms show characteristic southward loops over the Caspian Sea. The Arctic and Pacific coasts are cooler than the interior of Siberia, and indeed the climate of the Pacific coastal strip is described as decidedly unpleasant in summer owing to the chilly damp and foggy south-east winds that almost constantly blow from the sea. Lake Baikal cools its neighbourhood appreciably (Fig. 66).

The highest temperatures recorded are about 86° in the extreme north of Russia, in the tundra, and along the Baltic coast. It is a striking illustration of the regulating effect of bodies of water that no higher maxima occur in lat. 55° on the Baltic than in lat. 71° in the Arctic deltas of north-east Siberia. The summer maxima, like the summer means, are highest in the south of Turan, where they exceed 105°.

The distribution of temperature is far more uniform in July than in January:

	January.		*July.*	
	Mean Temp. °F.	*Absolute Min.* °F.	*Mean Temp.* °F.	*Absolute Max.* °F.
Batum	43	18	74	95
Tashkent	30	−15	81	109
Petrograd	15	−35	64	97
Moscow	12	−44	66	99
Tomsk	−3	−60	66	95
Yakutsk	−46	−84	66	102
Verkhoyansk	−59	−90	60	93
Range between extreme stations	102	108	21	16

A most important factor, especially in continental countries situated in the 'temperate' latitudes, is the range of temperature from summer to winter. In Russia the difference between summer and winter is so great that a statement of the mean annual temperature, which includes such widely different extremes, is without practical significance. The map showing lines of equal range of temperature (Fig. 67) is strongly reminiscent of that of the winter isotherms whose influence evidently outweighs that of the summer isotherms. The smallest range is in the west, over the Baltic, but even on the Baltic coast it is as much as 36°. Similarly on the coasts of the Arctic and Pacific Oceans, the Black Sea, the Caspian Sea, and Lake Baikal, the range is notably less than inland. In the interior away from sea influence the range increases from 36° in the west to 65° in the east of European Russia. Almost all Siberia except the Pacific littoral has the enormous range of over 70°. Round Verkhoyansk, in almost exactly the same position

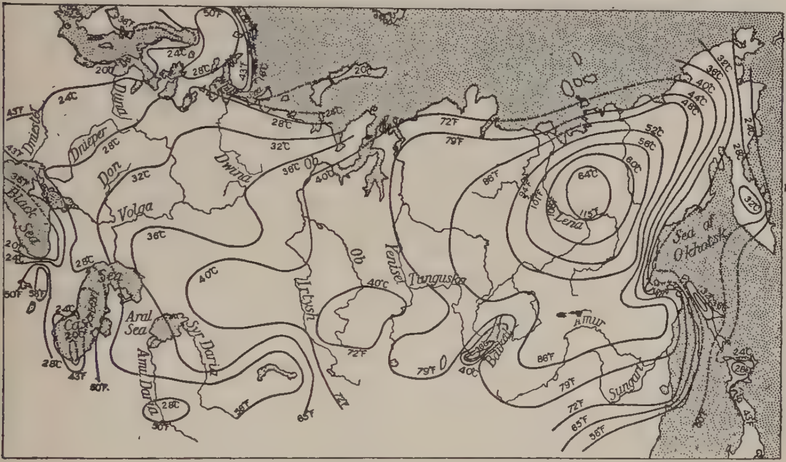

50F
36F
24C
20C
28C
43F
24C
Dwina
43F
Dniester
Dnieper
28C
Don
32C
28C
32C
Dwina
36C
Ob
40C
20C
28C
36F
Black Sea
Volga
36C
20
24
28C
Sea
40C
Ob
Yenisei
40C
Tunguska
Irtysh
50F
58F
24C
Caspian
28C
28C
43F
80F
Aral Sea
Syr Daria
Amu Daria
28C
50F
58F
65F
72F
79F
40C
72F
79F
86F
94F
101F
108F
64C
115F
Lena
52C
56C
60C
32C
36C
40C
44C
48C
24C
28C
32C
Sea of Okhotsk
Baikal
Amur
86F
79F
72F
65F
58F
Sungari
24C
28C
43F

FIG. 67. Mean Range of Temperature.

as the winter cold pole, we have the greatest range on the earth, over 100°. The following table shows more clearly how rapidly the range increases from west to east (see also Fig. 68):

	Mean Temperature.		
	January.	*July.*	*Range.*
	°F.	°F.	°F.
Riga . . .	23	64	41
Moscow . .	12	66	54
Kasan . .	7	67	60
Tobolsk . .	−2	66	68
Tomsk . .	−3	66	69
Yakutsk . .	−46	66	112

Where the range of temperature is so great it is evident that the change from month to month must be very rapid, especially in spring and autumn. At Verkhoyansk the mean temperature

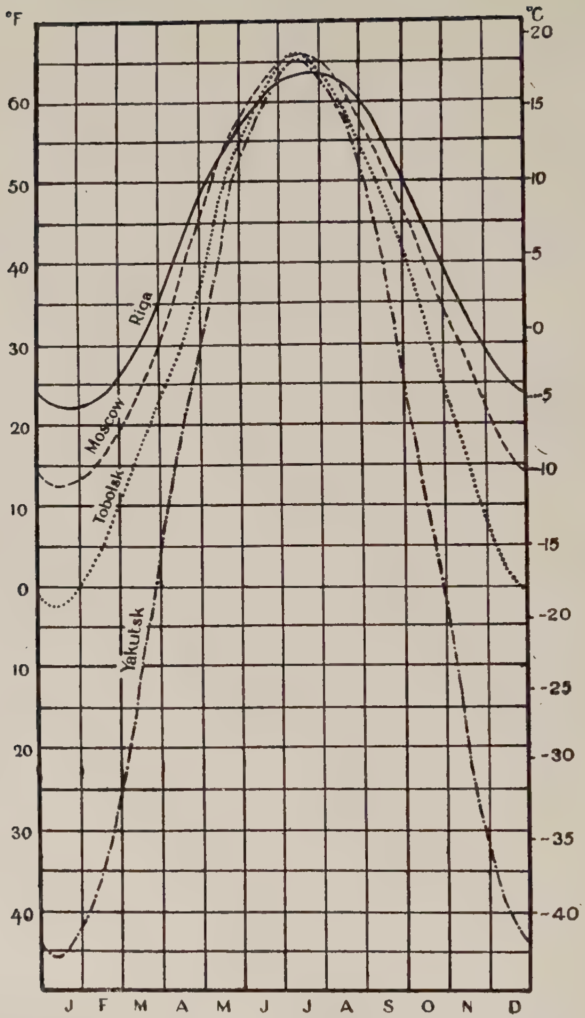


FIG. 68. Mean Temperature in the Russian Empire. The summer temperatures at the four stations are almost the same. The difference in range is due to the colder winters in the east.

drops 40° from October to November. This is an extreme case; but even in the west, at Moscow, there is a change of 15° from March to April.

Almost all the world over, outside the Tropics, autumn is warmer than spring, especially in maritime climates, although the altitude of the sun is greater in spring than in autumn. The air temperature lags behind the sun owing to such causes as a snow-covering requiring to be melted, wet ground to be dried, or, most important of all, the presence of a body of water with its conservative thermal tendency. The ordinary rule holds good in most of the Russian Empire, especially on the coasts of the Baltic and Black Seas, but Turan and the steppes of south-west Siberia are anomalous in having spring warmer than autumn :

	Mean Temperature.	
	April.	*October.*
	°F.	°F.
Tashkent	58	54
Irgis	44	42

Thus here the curve of air temperature follows closely that of insolation, there is little 'lag'. It has been pointed out also that, owing to the absence of trees, the winter winds are strong and the snow, never very great in amount, is swept away, so that the spring rise in temperature with the increasing power of the sun's rays is not delayed by the wasting of much energy on melting snow or drying the ground. There is no large body of water near. Hence the air temperature follows closely the sun, whose altitude is greater in April than in October. We find the same peculiarity at most stations in the interior of eastern Siberia, but on the coast of the Pacific the usual excess of heat in autumn is strongly marked :

	Mean Temperature.	
	April.	*October.*
	°F.	°F.
Verkhoyansk (interior)	7	5
Okhotsk (coast)	21	27

It is interesting to compare the temperature of the deserts of Turan with that of the Tarim Basin on the other side of the Pamirs, for the most part at a considerably greater altitude :

		Mean Temperature.		
	Altitude.	*Jan.*	*July.*	*Range.*
	Feet.	°F.	°F.	°F.
Turan.				
Petro-Alexandrovsk	290	23	83	60
Samarkand	2,360	32	78	46
E. Turkestan.				
Lukchun	−50	13	90	77
Kashgar	4,250	22	80	58

Both deserts are of the same general type, with cold winters and hot summers, but East Turkestan has considerably colder winters, somewhat warmer summers, and greater range of temperature.

Freezing of rivers and coasts. During winter even large rivers are frozen over in nearly all the Russian Empire. The duration of the ice (Fig. 69) is a most important element in the life of the people. In the south-west the Dniester and the middle Vistula are ice-bound for over seventy days in an average year. In the centre, including the middle and upper Volga, the period is 150 days, and in northern Russia over 200 days. The 120-day and the 160-day lines divide European Russia roughly into three equal parts, a southern where the rivers are frozen for less than 4 months, a central with 4 to 5½ months, and a northern with from 5½ to 7 months. In the whole of Siberia the rivers are frozen for at least 5 months, and in the extreme north running water is to be seen only for 3 months in the year. Many rivers and lakes are frozen to the bottom. The air temperature is below freezing-point for 10 to 20 days longer than the period during which the rivers are frozen, so that a general idea of both elements may be obtained from Fig. 69.

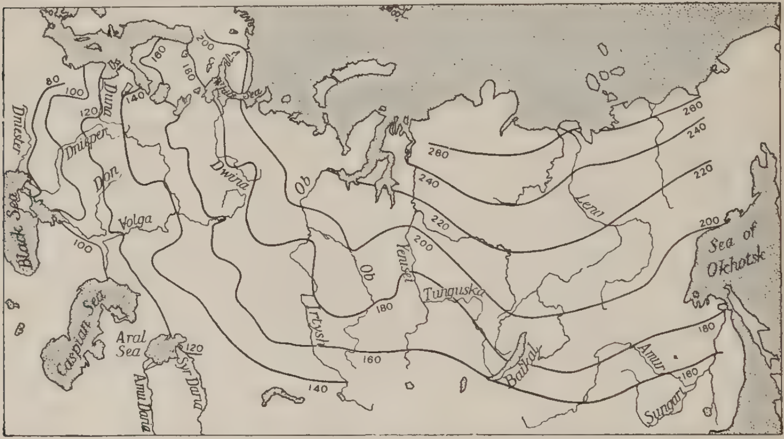

Dniester
80
100
120
Duna
140
160
180
200
Dnieper
Don
Dwina
Ob
Volga
Black Sea
100
Caspian Sea
Aral Sea
120
Amu Daria
Syr Daria
140
160
Irtysh
180
Ob
Yenisei
280
240
220
200
Tunguska
Baikal
Lena
280
240
220
200
Sea of Okhotsk
180
Amur
180
Sungari

Fig. 69. Lines showing the mean number of days the rivers are ice-bound each year.

Russia labours under another serious disadvantage in the freezing-up of her ports, even those on the Black Sea, the north-west shores of which, exposed to the cold north-east winds from the steppes, are ice-bound during January and February and on into March, a period of about 70 days. The Sea of Azov is frozen right across in mid-winter, and the shores are bordered with ice for a period of 80 days in the west, and over 100 days in the north-east. The northern half of the Caspian Sea is frozen near the coasts every winter, the ice remaining for some 100 days in the north. On the Baltic Sea Libau on the open coast is occasionally free of ice throughout the winter. The east half of the Gulf of Riga is blocked for 130 days, the shores of the Gulf of Finland for 140 to 150 days, from early November till the beginning of April. The eastern half of this gulf isfrozen over completely for about 3 months. In the Gulf of Bothnia the conditions are still worse, for the northern part freezes up in the middle of October and is not open again till the middle of May, after 210 days; the gulf is sometimes frozen almost across even as far south as the Åland Islands (Fig. 70).

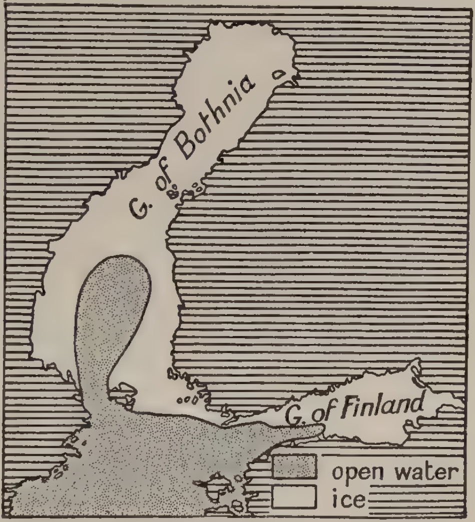


FIG. 70. The ice in the Gulf of Bothnia on March 1, 1905.

With regard to the north coast of European Russia it is an interesting fact that the part which lies farthest north is least obstructed by ice. This is the Murman coast, between Varanger Fiord and the White Sea, which derives such benefit from the Atlantic Drift that in some years there is no fixed ice, and only in the coldest years has the coast been ice-bound for as much as 5 months. During the European war Alexandrovsk on this coast usefully supplemented Archangel, which is 300 miles farther south, as a winter port on the Arctic shores of Russia. The coast east of the White Sea, being farther from the Atlantic warmth, has ice for 8 months in an average year. Similarly in the White Sea, the northern portion, thanks to the warm drift, is not frozen longer than Onega Bay, the most remote arm of this sea 200 miles south, the average duration of the ice being 200 days. The Gulf of Archangel freezes in the end of October, and remains blocked for 140 days. The port of Archangel is closed for 190 days.

The north coast of Siberia is ice-bound most of the year. The permanent ice-covering of the Arctic Ocean almost reaches Nova Zemlya and the coast of the Taimyr Peninsula, and it surrounds the northern islands of the New Siberian group. Vladivostok harbour is frozen from the middle of December till the beginning of April. Nikolaievsk at the mouth of the Amur is blocked for 220 days.

The Amur at Blagoveschensk begins to freeze in the beginning of September, and is frost-bound by the end of October. The ice in midwinter exceeds 5 feet in thickness.

Lake Baikal begins to freeze in November, but is not completely frozen over till the end of December. It remains frozen for 4½ months, and the ice is sometimes 9 feet thick. Sledges are the usual conveyance for crossing the lake during the 3 winter months. The ice begins to melt at the end of April.

Precipitation. As might be expected in a country of monotonous relief, the amount of precipitation is very uniform. In a wide belt extending through central Russia and south Siberia the rainfall is moderate, about 20 inches in European Russia, and over 20 inches in the extreme east, where it is brought by the south-east monsoon; the central part of this belt, from the Urals to the Amur, has about 15 inches. The tract north of this central belt has considerably less, under 8 inches in the tundra owing to the cold. South of it also the rainfall is deficient owing to the dry north-east winds which blow throughout the year. The driest region includes the deserts of Kara Kum and Kisil Kum, which have less than 4 inches. Between them and the central belt are the steppes with from 8 to 15 inches. Even the coast of the Black Sea between the mouth of the Dneister and the Crimea has only about 12 inches. But the Black Sea coast farther east, at the foot of the Caucasus, has abundant rainfall, over 60 inches in many parts; this is the rainiest part of the Empire. The rain is of the 'west coast' type of the Mediterranean lands; in winter low-pressure systems form over the Black Sea and cause south and south-east winds on this coast, and abundant rainfall; but the north-west coast of the Black Sea has prevailing north-east winds from the steppes, and the precipitation is scanty.

Over most of the Russian Empire summer is the rainiest season (Fig. 71), for in winter the outflowing winds from the continental high pressures hinder the ingress of moisture. But in summer abundant moisture comes in from both west and east; the winds from the Arctic Ocean are cold and their moisture capacity is increased as they are warmed over the land, so that but little rain is derived from them. The maximum rainfall is in the late summer months, July and August, when the inflow of moist air is strongest, and thunderstorms are most frequent. A large proportion of the rain falls in thunderstorms on summer afternoons. The rainfall of east Siberia is brought by the south-east monsoon of Eastern Asia. It falls almost entirely in summer, mostly in late summer; the amount decreases towards the north. At Okhotsk the rain for the most part takes the form of drizzle and mist, and the total is only 7 inches per annum. Vladivostok has 15 inches. The extreme west and north of European Russia receive most rain in autumn, derived from the cyclones of the westerlies which are then very active, and are not yet kept at bay by the high pressures which cover the continent in winter.

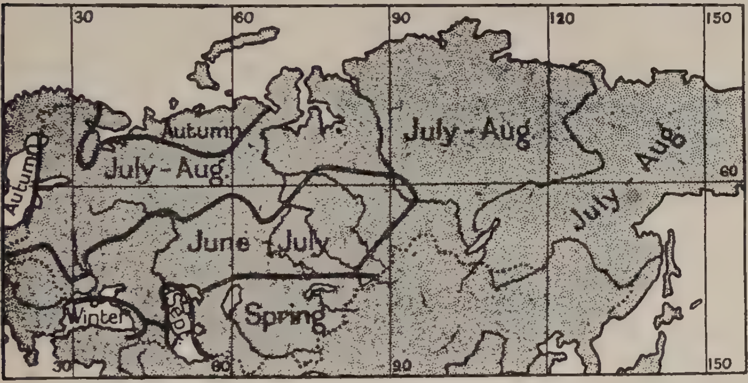


FIG. 71. Period of Heaviest Precipitation.

The region with a winter rainfall maximum is very small, including only the south coast of the Crimea and the east coast of the Black Sea, already referred to as having the heaviest rainfall in the Russian Empire. These small areas are the only representatives in Russia of the 'Mediterranean' climate. Most of the rain falls in autumn and winter, but no season can be called dry. On the south and west coasts of the Caspian also, and throughout Turan as far as Lake Balkash, the rainfall is heaviest in the winter half-year, but the total rainfall is so small and the winters are so cold that the climate cannot be classed with that of the Mediterranean shores. The sharp contrast already noted in the temperature between the north and south of the Crimea holds equally in respect of rainfall. South of the Yaila Mountains it exceeds 20 inches a year, most of it falling in the winter; the steppes on the north have only 12 inches, with the maximum in early summer.

Turan has most of its scant rainfall in March and April. The months December to May all have more than the normal proportion of the yearly total, and the summer months, especially August and September, are particularly dry. The steppes to the north of the desert also have spring rain, with the maximum in May and June, when there are violent thunderstorms with copious downpours. Indeed, the rain is so heavy while it lasts that only a small portion of it is able to percolate into the ground and become available for vegetation. Most runs off at once and is wasted. The cause of these early summer showers seems to be the great and rapid heating of the dry ground by the sun while the air some few hundred feet above is still cold. These conditions are favourable for convectional overturnings which produce thunderstorms. Later in the summer the heat is equally great, but more evenly distributed, and there is a steadier current of air, so that large temperature differences are less likely to occur.

Though there is a summer maximum nearly everywhere, winter is by no means without precipitation, which is practically all in the form of snow from December to March inclusive in European Russia, and from November to April in Siberia. This winter snowfall is heaviest in the belt of the taiga. Here a snow layer 3 feet deep is not uncommon, and the depth is far greater in drifts, for even in winter, in spite of the high pressures, cyclones sometimes make their way far into the continent. The snow lies deepest in the forest, largely on account of the shelter provided by the trees. But there are no permanent snow-fields in Siberia, in spite of the intense winter cold, owing to the not very abundant snow being readily melted in the long summer days. In spring, as it melts slowly, the moisture saturates the ground, and the conditions are ideal for tree growth. The snow covering is very beneficial in another way. In January 1893, there was a layer of loose dry snow, 20 inches deep, at Petrograd. The temperature on the surface of the snow was −39°, but on the ground under the snow 27°. On a neighbouring piece of ground where there was no snow the temperature was −31° (records quoted by Woeikof). Hence it is clear that the snow layer, being a poor conductor of heat, acts as a most valuable blanket, protecting the ground from excessive cold. Over large tracts in Siberia the soil at a certain depth is permanently frozen. The thickness of the layer of snow on the ground in winter is a factor in determining whether or not this permanently frozen layer occurs. In Transbaikalia it is found with a mean air temperature of 25°; here there is little snow; but not at Turukhansk (lat. 66° N., on the River Yenisei), though the mean air temperature is 17°, one reason being that the surface is covered with abundant snow throughout the winter. On the steppes south of the taiga there is much less snow, and what falls is often swept away by the strong north-east winds. Even at Krasnoyarsk there is often not enough snow for sledges to be used. We have here an instructive instance of the interaction of climate and vegetation. The trees of the taiga provide shelter, and therefore snow lies deep for a long period, keeping the ground warm, and providing moisture when it melts in spring. But the steppes are treeless and windy, snow does not lie, the ground temperature is very low, and there is no moisture in spring to saturate the earth and enable trees to grow; grasses alone flourish. The animals of the tundra, and also many from the steppes, take refuge in winter in the intermediate forest belt, for they find there a shelter from the cold winds of the open country, as well as a certain amount of food. Fig. 72 illustrates the three main rainfall régimes.

When the snow melts in spring the rivers rise in heavy flood. In May the Volga swells to 25 feet above its mean level at Samara, and to 7 feet above the mean at Astrakhan, where the floods spread to a breadth of 25 miles. The rivers that flow northward are flooded in their upper courses before the ice melts farther north. The lower parts of their basins are often inundated, and there are widespread tracts of marsh. The floods of the Amur occur in summer, being due to the heavy summer rains, not in spring, for there is not very much snow to melt in its basin. The floods are very extensive and often do great damage.

The valleys that open on to the deserts of Turan from the mountains on the east owe their fertility to irrigation from the streams, which are fed by the melting of the snow which has collected on the mountains during the winter. Such is the Syr Daria, which waters the gardens of Ferghana abundantly all summer. The streams that descend from Khorasan and Afghanistan are flooded in spring, but almost dry up in summer, since the snow is less abundant round their sources.

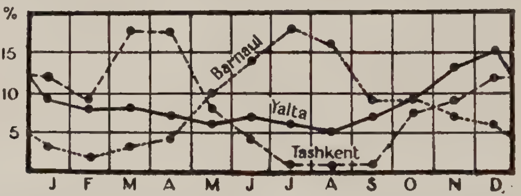


Fig. 72. Mean Rainfall (monthly percentage of annual total). Barnaul represents the taiga régime, maximum in late summer; Tashkent the steppe régime, maximum in spring; Yalta the Mediterranean régime, maximum in winter.

Cloudiness. The annual curve of cloudiness is not necessarily parallel with that of rainfall. In European Russia the cloudiest season is winter, which is the least rainy in most parts ; in winter on an average $\frac{6}{10}$ to $\frac{8}{10}$ of the sky is covered. The centre of Russia is about as cloudy as the south, where winter is the rainiest season. In summer the cloudiness varies very much, but is everywhere less than in winter. In the deserts round Bokhara the cloud covering is only $\frac{1}{10}$; the summer drought is here accompanied by almost cloudless skies. In western Siberia winter is the cloudiest season, with an average cloudiness of about $\frac{6}{10}$. In summer the clearest skies of Siberia are those of the steppes ; in eastern Siberia the summer monsoon brings abundant clouds.

It may be found useful if in conclusion we sum up briefly the main features of the climate of the vast area with which we have been dealing by describing in a few words its chief climatic divisions (Fig. 73). Where isotherms are used as boundaries it must be remembered that they denote sea-level temperatures. Hilly land introduces complications which are not considered.

1. The tundra is characterized not so much by its cold winters—those of central Siberia are far colder—as by its cool summers. The mean July temperature is less than 50° and we may use the 50° isotherm as the boundary of the region. The ground is frozen hard most of the year, and at a few feet below the surface it is frozen permanently. The surface thaws for a month or two in summer, but is then waterlogged, except on south-facing slopes. The precipitation is small, but the air is damp and raw.

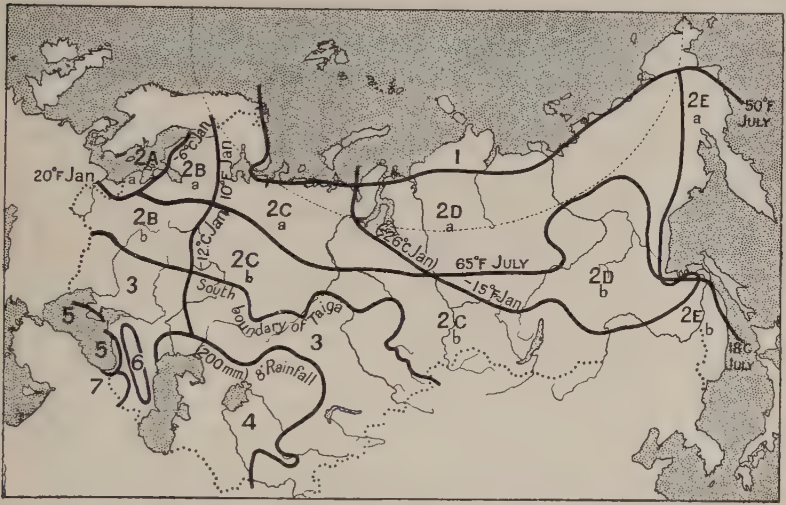

20°F Jan
2A
a
-6°C Jan
2B
a
10°F Jan
2B
b
2C
a
(-12°C Jan)
2C
b
3
South boundary of Taiga
5
5
6
7
(200mm) 8" Rainfall
4
3
1
2D
a
(-26°C Jan)
65°F July
2D
b
-15°F Jan
2C
b
2E
a
50°F July
2E
b
18°C July

FIG. 73. The major Climate Regions of the Russian Empire.

2. This is an extensive region which has its rainfall maximum in late summer, but no season is without precipitation; there is much snow in winter. Winter is very cold, the thermometer rarely rising above freezing-point, but summer is warm, the mean July temperature exceeding 50°.

Subdivisions according to temperature are necessary; first according to the winter cold, which becomes more intense as we go east into Siberia, and secondly according to the summer heat, which increases from north to south. But the differences in the intensity of the winter cold, great as they are, are probably of no very great importance for the plant world where the January mean is below about 10° F.

The 65° isotherm for July, which has a generally east to west trend, gives us a northern subdivision, (*a*), with mean July temperature between 50° and 65°, and a southern, (*b*), with July temperature above 65°.

2 (A). The Baltic coast has a comparatively mild winter, January mean over 20°, and a somewhat cool summer, the July mean being under 65°; the warmer subdivision (*b*) does not appear here. The rainfall exceeds 20 inches per annum, autumn being the rainiest season. The cyclones of the westerlies exercise an important control on the weather.

2 (B). West-central Russia; here the winters are colder.

2 (C). East Russia and west Siberia have very cold winters indeed, the January mean being 10° in the west, −15° in the east. Rainfall is 20 inches per annum to the west of the Urals, only 8 to 16 inches to the east. The northern subdivision (*a*) has less rain than (*b*).

2 (D). Central Siberia has the coldest winters known anywhere, and an extreme range of temperature. The air is dry and clear in winter, and the sky is much less cloudy than in 2 (C). The rainfall is decidedly low in (*a*), from 8 to 12 inches in (*b*).

2 (E). The east coast is distinguished chiefly by its damp, cloudy, cool summer with much fog and drizzle. Winter is cold, but less so than in the interior; there are almost constant north-west winds, strongest where there is no mountain shelter; Nikolaievsk is 5° colder in January than Aian, almost 4° of latitude farther north, owing to the winds which sweep down the Amur valley; the sky is very clear and there is hardly any rain. Autumn is the driest and most pleasant season. The Amur basin has very heavy rain in summer and the ground is waterlogged; the winters, owing to the strong wind, are more trying than in the far interior of Siberia, and altogether the climate is much less healthy and agreeable.

3. The boundary between this division and 2 is the line separating the taiga from the steppes. In the steppes the rainfall is from 8 to 16 inches, which is not abundant when the dry air and

the heat of summer are taken into account. The rainy season is spring and early summer, when most of the rain falls in heavy thunderstorms, so heavy that the run-off is excessive, and most of the water is lost to vegetation, only the surface of the soil being moistened. The prevailing winds are north-east, dry and strong throughout the year; in winter they often blow with gale force as the Buran. Nearly all the snow which falls is swept away by the wind and the ground is left bare, exposed to the full rigour of the winter frost, which is very severe. Summer is hot; spring is as warm as, or warmer than autumn. The range of temperature is great. Thus all factors combine to form a climate very unfavourable to tree-growth, and grass is the natural vegetation.

We may subdivide 3 into a western division with a mean January temperature above 10°, and an eastern with a mean January temperature below 10°.

4. Towards the south the rainfall becomes still less, and we include in 4 the area with less than 8 inches of rain per annum. There is only very poor grass on its margins, surrounding the bare sand-dunes of the deserts of Turan where the annual rainfall is less than 4 inches. The winters are very cold for the latitude, with a mean temperature far below freezing-point, except in the extreme south. The summers are very hot indeed, the mean July temperature being over 85° in the south. The air is very dry and the sky almost cloudless.

5. The south of the Crimea has mild, rainy winters (mean January temperature above freezing-point) and hot sunny summers; the vegetation is of the true Mediterranean type. The eastern shores of the Black Sea have far more rain, which is over-abundant all the year round.

6. The Caucasus climate is of the usual mountain type.

7. Includes Georgia, with its very cold winters but hot summers.

STATISTICS

MEAN TEMPERATURE (°F.)

INDIA, CEYLON, AND BURMA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Colombo	24	*79·0*	79·7	80·6	81·5	**82·1**	80·4	*80·0*	**80·5**	80·4	79·3	79·5	79·2	80·2	3·1
Trincomalee	99	78·2	79·2	80·4	83·3	**84·8**	83·8	*83·1*	**83·5**	82·8	80·7	79·2	*77·7*	81·4	7·1
Calicut	27	*77·8*	79·8	81·6	**83·6**	83·1	78·5	*76·7*	77·4	78·3	79·1	**79·5**	78·3	79·5	6·9
Bombay	37	*74·5*	74·8	78·0	82·1	**84·6**	82·4	79·5	*79·4*	79·4	**80·7**	79·3	76·4	79·3	10·1
Poona	1,846	69·8	73·9	80·1	**83·9**	83·8	78·7	74·9	*73·7*	74·4	**76·2**	72·5	*68·9*	75·9	15·0
Bangalore	3,021	67·5	72·0	76·7	**79·9**	78·5	74·0	72·0	71·8	71·8	71·8	69·6	*67·5*	72·8	12·4
Madras	22	*75·3*	76·6	79·5	84·1	**88·7**	88·4	85·7	84·5	83·9	80·8	77·9	75·7	81·8	13·4
Akyab	20	*69·5*	72·8	79·2	83·4	**85·0**	82·2	81·3	*81·1*	**82·1**	81·6	77·5	71·7	78·9	15·5
Rangoon	18	*74·7*	77·3	81·2	**85·0**	82·2	79·5	78·8	*78·7*	79·1	**80·0**	78·3	75·6	79·2	10·3
Mandalay	250	*68·8*	73·8	82·1	**89·2**	88·5	85·4	85·2	84·7	83·5	82·5	75·9	69·5	80·8	20·4
Calcutta	21	*65·2*	70·3	79·3	85·0	**85·7**	84·5	83·0	*82·4*	**82·6**	80·0	72·4	65·3	77·9	20·5
Patna	183	*60·8*	65·3	76·9	86·2	**88·0**	86·4	83·5	*83·1*	**83·3**	79·5	70·1	62·2	77·1	27·2
Benares	267	*60·0*	65·3	76·6	86·8	**91·3**	89·4	84·1	83·1	83·0	77·9	67·8	60·2	77·2	31·3
Allahabad	309	*59·5*	64·9	76·8	87·6	**92·5**	90·8	84·5	83·2	83·0	77·6	67·5	59·8	77·3	33·0
Cawnpore	416	*58·8*	63·9	74·9	87·0	**92·6**	90·9	85·6	*83·0*	**83·4**	77·4	67·8	59·9	77·1	33·8
Delhi	718	*57·9*	62·2	74·1	86·2	91·7	**92·2**	86·4	84·5	83·9	**78·5**	67·6	59·6	77·1	34·3
Jaipur	1,431	*59·9*	64·2	74·9	86·3	**91·6**	90·6	84·7	82·3	82·4	77·9	68·9	61·5	77·1	31·7
Hoshangabad	1,006	65·6	70·3	80·3	89·6	**93·2**	87·6	79·6	78·3	79·4	76·9	70·6	*65·3*	78·1	27·9
Pachmarhi	3,528	*57·0*	62·4	73·8	81·7	**84·3**	77·9	71·8	69·5	70·5	67·7	62·0	57·3	69·7	27·3
Lahore	702	*53·0*	57·3	69·0	80·9	88·9	**93·0**	89·1	87·1	84·8	75·7	63·2	54·6	74·7	40·0
Mooltan	420	*55·6*	59·8	71·6	82·0	91·4	**94·9**	92·7	90·4	88·0	78·6	67·1	57·7	77·5	39·3
Jacobabad	186	*57·3*	62·4	74·5	85·5	94·2	**97·7**	95·0	91·6	88·8	79·2	67·5	58·9	79·3	40·4
Karachi	13	*65·3*	68·4	75·0	80·6	84·7	**86·8**	84·3	82·4	82·0	80·0	74·0	67·4	77·6	21·5
Peshawar	1,113	*49·7*	53·3	63·3	73·5	84·0	**91·2**	90·3	87·6	82·1	71·4	59·1	51·1	71·4	41·5
Darjiling	7,376	*40·1*	41·6	49·7	56·2	58·3	59·9	**61·5**	60·9	59·4	55·2	47·8	41·8	52·7	21·4
Simla	7,232	*38·8*	40·6	51·5	59·3	66·0	**66·9**	64·3	62·8	60·9	56·7	50·1	43·4	55·1	28·1
Srinagar	5,204	*30·7*	33·0	45·1	55·7	63·9	69·9	**73·0**	70·8	64·0	53·2	44·0	36·3	53·3	42·3
Leh	11,503	*17·3*	18·8	30·9	42·9	49·8	57·8	**62·6**	61·0	53·7	42·7	32·1	22·1	40·9	45·3

CHINA

Station.	Alt. Feet.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.	Range.
Charbin	525	*—1·7*	5·4	24·1	42·3	55·9	66·0	**72·1**	69·4	57·9	40·1	21·2	3·2	37·9	73·8
Peking	131	*23·5*	29·3	41·0	56·7	67·8	76·1	**78·8**	76·5	67·6	54·5	38·5	27·3	53·1	55·3
Shanghai	33	*37·6*	39·2	46·0	56·3	65·5	73·4	**80·4**	80·2	72·9	63·3	51·8	42·1	59·0	42·8
Hankow	118	*40·1*	42·6	50·4	61·9	71·4	79·7	**85·5**	85·5	76·6	66·6	55·2	44·6	63·3	45·4
Chengtu	1,509	*43·9*	45·0	53·2	62·6	70·3	75·7	**79·2**	77·7	70·3	63·1	54·0	46·6	61·9	35·3
Hong Kong	108	59·7	*57·7*	63·0	70·3	76·8	80·6	**81·7**	81·1	80·2	76·1	69·1	62·6	71·6	24·0
Hué	23	69·1	*67·5*	74·1	80·2	83·3	**85·1**	*84·2*	**85·1**	81·3	77·7	73·0	70·3	77·7	17·6
JAPAN															
Taihoku (Formosa)	30	60·3	*57·2*	62·4	69·3	74·8	79·9	**82·2**	81·9	79·2	73·9	67·3	62·1	70·9	25·0
Kagoshima	394	*44·6*	44·6	51·1	59·5	65·3	71·1	78·1	**79·5**	75·2	66·2	56·7	47·8	61·5	34·9
Osaka	20	*39·0*	39·4	45·3	56·1	63·7	71·8	78·6	**81·3**	74·1	62·2	51·8	43·0	59·0	42·3
Tokio	69	*37·2*	38·3	44·1	54·3	61·5	68·9	75·0	**77·7**	71·6	60·6	50·4	41·4	56·8	40·5
Akita	20	*29·8*	29·8	35·6	47·3	55·6	64·2	71·1	**74·1**	66·7	54·5	44·1	34·7	50·5	44·3
Sapporo	56	*20·8*	22·3	28·8	41·2	50·7	58·6	66·0	**69·1**	61·0	48·9	37·0	26·2	44·2	48·3
SOUTH-EAST ASIA AND THE EAST INDIES															
Penang	23	79·7	80·1	81·3	**81·7**	81·5	80·6	80·2	79·9	79·5	79·7	79·2	*78·8*	80·2	2·9
Singapore	10	*78·3*	79·0	80·2	80·8	**81·5**	81·1	81·0	80·6	80·4	80·1	79·3	78·6	80·1	3·2
Sandakan (British N. Borneo)	98	79·2	79·5	80·8	81·9	**81·9**	80·6	80·6	80·8	80·8	80·8	80·2	*79·0*	80·4	2·9
Batavia	23	77·9	*77·7*	78·6	79·3	**79·7**	79·0	*78·4*	78·8	79·5	**79·7**	79·2	78·3	78·8	2·0
Amboina (Moluccas)	40	80·8	**81·0**	80·6	79·3	79·3	78·4	*77·4*	77·7	78·1	79·2	80·4	80·8	79·3	3·6
SOUTH-WEST ASIA															
Aden	94	*75·7*	76·6	78·5	81·4	86·0	**88·6**	87·6	*85·9*	**87·2**	82·4	78·8	76·6	82·1	12·9
Basra	26	*49·8*	55·8	64·1	74·0	84·1	90·1	**92·5**	91·9	86·9	76·7	44·7	53·2	71·9	42·7
Bagdad	220	*46·8*	53·0	60·3	70·2	80·7	89·6	**94·0**	93·8	86·9	76·3	60·7	50·3	71·9	47·2
Mosul	870	*40·2*	45·6	53·1	61·4	77·7	84·4	**90·5**	89·4	82·0	70·6	61·1	45·4	66·8	50·3
Teheran	4,002	*33·6*	42·3	48·1	61·3	71·3	80·0	**84·9**	83·2	77·4	65·8	51·3	41·7	61·7	51·3
Kabul	6,250	*30·7*	35·7	46·7	58·9	68·0	73·2	**76·6**	75·5	68·8	58·3	50·8	40·4	57·0	45·9
Quetta	5,500	*39·6*	41·1	51·1	59·5	67·1	74·2	**77·8**	75·0	66·6	55·6	47·4	42·2	58·1	38·2

MEAN TEMPERATURE (°F.), *continued*

THE HEART OF ASIA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Kashgar	4,255	*21·8*	33·6	46·5	60·9	69·6	77·0	**79·7**	76·2	68·9	55·5	39·9	25·6	54·6	57·9
Lukchun	−50	*13·2*	26·9	45·4	66·2	75·4	85·4	**90·5**	85·4	73·7	55·4	32·9	20·9	56·0	77·3
Urga	3,800	*−15·2*	−4·4	13·0	33·7	47·5	59·0	**63·5**	59·0	47·4	28·7	7·9	−7·5	27·7	78·7

RUSSIAN EMPIRE

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Mariehamn	30	27·3	*23·9*	26·8	35·2	44·9	54·5	**59·5**	57·7	50·5	42·6	35·8	30·2	40·8	35·6
Petrograd	30	*15·3*	16·9	23·5	35·8	47·7	58·6	**63·9**	61·0	51·4	40·1	29·1	20·1	38·7	48·6
Riga	50	*22·8*	23·5	29·1	40·5	51·3	60·3	**64·2**	63·0	55·0	43·9	33·8	26·2	42·8	41·4
Archangel	50	*7·3*	9·3	18·5	29·7	40·8	53·6	**60·4**	56·8	46·8	34·5	21·6	11·5	32·5	53·1
Kola	33	*10·8*	12·4	18·1	28·8	38·7	48·6	**54·1**	51·8	42·8	31·1	19·4	12·4	30·7	43·3
Moscow	480	*12·2*	14·7	23·4	38·3	53·1	61·5	**66·0**	62·8	52·2	39·7	27·7	17·2	39·0	53·8
Kasan	250	*7·2*	9·7	19·6	37·8	53·8	62·8	**67·5**	63·3	51·4	38·7	25·2	11·1	37·4	60·3
Warsaw	390	*25·9*	27·0	32·9	44·8	54·8	63·1	**65·8**	63·7	56·1	46·0	34·9	27·3	45·1	39·9
Kiev	590	*20·8*	22·5	30·7	44·4	56·8	63·7	**66·6**	65·1	56·8	45·5	34·2	24·1	44·2	45·8
Kursk	690	*14·2*	17·2	25·3	40·5	55·6	63·3	**66·7**	65·1	55·0	43·5	29·5	19·9	41·4	42·5
Saratov	295	*11·5*	14·9	23·9	41·0	58·6	67·1	**72·1**	68·9	57·4	43·3	28·9	17·6	42·1	60·6
Orenburg	360	*3·4*	6·1	16·5	37·9	57·7	65·8	**70·9**	67·3	55·4	39·2	24·1	10·6	37·9	67·5
Odessa	210	*25·3*	27·7	34·9	47·5	59·2	68·0	**72·7**	70·9	62·1	51·8	41·0	30·6	49·3	47·4
Astrakhan	−50	*19·0*	20·8	31·8	48·7	64·2	73·0	**77·9**	74·5	63·7	50·4	37·8	25·9	48·9	58·9
Yalta	135	38·3	*38·3*	43·7	51·3	61·3	69·3	**75·6**	75·6	67·1	58·3	50·0	44·1	56·1	37·3
Batum	20	*43·0*	43·9	46·6	52·2	60·3	68·4	73·4	**73·8**	67·8	61·9	53·2	48·2	57·7	30·8
Baku	0	*38·1*	38·1	43·3	52·2	64·2	73·0	**78·8**	78·6	71·4	61·9	52·5	43·2	57·9	40·7
Tiflis	1,350	*32·4*	35·8	44·2	53·6	63·9	70·3	**76·1**	75·7	67·1	57·4	45·9	36·9	54·9	43·7
Kars	5,725	*7·5*	13·5	23·9	38·1	49·1	56·8	62·4	**63·3**	55·4	45·5	30·0	17·8	52·3	55·8
Petro-Alexandrowsk	295	*22·6*	28·8	42·8	57·9	72·5	79·7	**83·1**	79·0	67·3	52·0	38·5	29·7	54·5	60·5
Samarkand	2,362	*32·2*	36·7	46·0	57·0	68·2	75·7	**77·9**	74·7	66·4	54·1	44·4	38·5	55·9	45·7
Tashkent	1,610	*30·0*	34·2	47·1	58·1	69·6	77·4	**80·8**	77·0	66·6	53·6	43·2	36·0	56·1	50·8

RUSSIAN EMPIRE (*continued*)

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Irgis	360	*3·4*	4·1	18·9	43·7	62·6	72·3	**76·1**	72·7	59·4	42·3	26·1	10·9	41·0	72·7
Semipalatinsk	590	*0·5*	1·8	14·4	38·3	57·2	68·0	**72·0**	67·3	54·9	38·1	20·1	6·1	36·5	71·5
Barnaul	480	*−2·2*	1·4	13·5	33·3	50·9	62·1	**67·1**	61·7	50·0	34·9	15·6	3·7	32·7	69·3
Tobolsk	340	*−2·2*	4·5	15·4	33·1	47·8	59·5	**66·4**	60·1	48·0	32·7	13·8	1·4	31·6	68·6
Beresov	100	*−10·7*	−1·7	10·8	21·0	34·5	50·5	**61·3**	55·6	41·7	25·0	4·3	−7·1	23·7	72·0
Tomsk	390	*−3·3*	1·4	14·0	29·8	45·1	59·0	**65·7**	59·5	47·8	32·2	10·8	1·0	30·2	69·0
Irkutsk	1,610	*−5·4*	0·9	16·5	34·9	48·0	59·2	**65·1**	60·4	48·2	33·3	12·9	0·7	31·3	70·5
Yakutsk	330	*−45·9*	−35·1	−10·1	15·8	40·6	59·0	**66·2**	59·5	42·4	16·2	−20·9	−40·5	12·2	112·1
Verkhoyansk	330	*−58·9*	−47·4	−24·0	7·3	35·4	54·5	**59·7**	49·8	36·3	5·2	−34·4	−52·6	2·7	118·6
Okhotsk	30	*−10·5*	−7·2	6·6	21·4	35·1	45·3	54·9	**55·2**	46·4	26·6	5·5	−7·8	22·6	65·7
Vladivostok	50	*4·8*	12·4	26·4	39·2	48·7	56·8	66·0	**69·4**	61·3	48·6	29·8	13·6	39·7	64·6

MEAN RAINFALL (inches)

INDIA, CEYLON, AND BURMA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Colombo	25	3·5	*1·9*	4·5	7·8	**13·0**	7·7	6·5	*3·0*	5·9	**13·1**	11·0	5·2	83·1
Trincomalee	110	6·6	2·1	*1·6*	2·0	**2·4**	*1·3*	2·0	4·1	4·5	8·2	13·9	**14·4**	63·1
Calicut	27	0·3	*0·2*	0·6	3·2	9·5	**35·0**	29·8	15·3	8·4	10·3	4·9	1·1	118·6
Bombay	37	0·1	*0*	0·1	0	0·7	20·6	**27·3**	16·0	11·8	2·4	0·4	0	79·4
Poona	1,846	0·1	*0·1*	0·1	0·6	1·4	5·4	**7·2**	3·7	5·1	4·0	1·1	0·2	28·9
Bangalore	3,021	*0·2*	0·3	0·6	1·2	**4·5**	*3·0*	4·1	5·8	**7·4**	6·2	2·4	0·4	36·0
Madras	22	1·1	0·3	*0·3*	0·6	1·8	2·0	3·8	4·5	4·9	11·2	**13·6**	5·4	49·6
Tuticorin	30	1·1	0·6	1·0	1·6	0·9	0·2	*0·1*	0·3	0·6	5·3	**7·1**	3·2	21·9
Akyab	20	*0·1*	0·2	0·5	2·1	14·0	46·9	**54·8**	45·2	22·6	10·9	5·5	0·8	203·4
Rangoon	18	0·2	*0·2*	0·3	1·6	12·0	18·0	**21·4**	19·9	15·3	6·9	2·8	0·4	99·0
Mandalay	250	0·1	*0·1*	0·2	1·1	**5·8**	5·5	*3·3*	4·6	**5·7**	4·7	1·6	0·4	33·2
Calcutta	21	0·4	1·1	1·4	2·0	5·0	11·2	**12·1**	11·5	9·0	4·3	0·5	*0·2*	58·8
Dacca	35	0·3	1·2	2·6	5·4	9·8	**13·6**	12·8	13·1	9·8	4·6	0·8	*0·2*	74·2

INDIA, CEYLON, AND BURMA (*continued*)

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Cherrapunji . . .	4,309	0·7	2·1	11·7	30·8	46·2	96·8	**98·2**	76·5	46·1	16·7	1·9	*0·2*	427·8
Shillong	4,920	0·4	0·8	1·9	4·7	10·1	**16·2**	13·4	13·0	12·8	6·4	1·2	*0·3*	81·1
Gopalpur	21	*0·3*	0·6	0·5	0·8	1·9	5·6	6·1	7·3	7·3	**8·5**	3·7	0·7	43·3
Raipur	970	0·4	0·7	0·7	0·7	1·0	9·5	**14·3**	13·3	7·4	2·0	0·4	*0·2*	50·4
Patna	183	0·6	**0·7**	0·4	*0·3*	1·7	7·9	11·6	**12·8**	8·4	2·6	0·2	*0·1*	47·3
Benares	267	**0·7**	0·6	0·4	*0·2*	0·6	4·8	**12·1**	11·6	7·1	2·1	0·2	*0·2*	40·6
Allahabad	309	**0·7**	0·5	0·3	*0·1*	0·3	4·5	**11·4**	11·1	6·0	2·2	0·2	*0·2*	37·5
Cawnpore	416	**0·6**	0·5	0·3	*0·2*	0·4	3·1	9·7	**10·2**	5·5	1·2	*0·2*	0·3	32·1
Delhi	718	**1·0**	0·6	0·5	*0·4*	0·7	2·9	**7·6**	7·0	4·7	0·5	*0·1*	0·4	26·2
Jaipur (Rajputana) . .	1,431	**0·4**	0·3	0·4	*0·2*	0·6	2·6	**8·3**	7·3	3·2	0·3	*0·1*	0·3	24·0
Lahore	702	0·9	**1·0**	0·8	*0·5*	0·7	1·4	**5·1**	4·7	2·3	0·3	*0·1*	0·4	18·1
Mooltan	420	0·4	0·3	**0·4**	*0·3*	0·3	0·5	**1·9**	1·7	0·6	0·1	*0·1*	0·2	6·8
Jacobabad	186	0·3	**0·3**	0·3	0·2	*0·1*	0·2	1·0	**1·1**	0·3	*0*	0·1	0·1	4·0
Karachi	13	0·5	**0·5**	0·4	0·2	*0·1*	0·9	**2·9**	1·5	0·5	*0*	0·1	0·1	7·6
Peshawar	1,113	1·5	1·2	**2·0**	1·7	0·7	*0·3*	1·2	**2·1**	0·8	*0·2*	0·4	0·6	12·8
Darjiling	7,376	0·6	1·1	1·8	3·8	8·7	24·9	**32·3**	26·1	18·4	4·5	0·8	*0·2*	122·7
Simla	7,232	2·5	2·7	2·7	2·3	2·8	7·2	17·0	**17·4**	5·9	1·0	*0·5*	1·0	63·1
Srinagar	5,204	2·7	2·8	3·6	**3·8**	2·3	*1·5*	2·2	**2·3**	1·6	1·2	*0·4*	1·5	25·7
Leh	11,503	**0·4**	0·3	0·3	0·2	*0·2*	0·2	0·5	**0·5**	0·3	0·2	*0*	0·2	3·2

CHINA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Mukden	144	*0·2*	0·2	0·6	1·0	2·4	**3·2**	**6·7**	4·3	2·6	1·7	0·5	0·2	23·5
Peking	131	*0·1*	0·2	0·2	0·6	1·4	3·0	**9·4**	6·3	2·6	0·6	0·3	0·1	24·9
Hankow	118	2·1	1·1	2·8	4·8	5·0	7·0	**8·6**	4·6	2·2	3·9	1·1	*0·6*	43·8
Shanghai	23	2·8	2·0	3·9	4·4	**3·3**	6·6	**7·4**	4·7	3·9	3·7	1·7	*1·3*	45·8
Ichang	167	0·9	1·1	1·9	3·8	4·2	6·6	**7·2**	5·9	3·8	3·9	1·0	*0·4*	40·7
Chungking	750	*0·7*	0·7	1·2	3·6	4·1	**6·8**	5·7	*4·1*	**5·6**	4·9	2·1	0·9	40·4
Fuchou	66	*1·7*	4·1	5·3	4·4	5·6	**8·1**	*6·7*	7·5	**9·2**	2·8	2·1	2·2	59·7
Hong Kong . . .	108	1·4	*1·1*	2·6	5·5	10·2	**15·1**	*11·4*	**14·0**	11·5	4·5	1·6	1·3	80·1
Hue	23	4·0	4·8	*1·8*	2·4	**3·6**	2·8	3·4	4·0	16·2	**26·3**	22·4	10·2	102·0

Station.	Alt. Feet.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
JAPAN														
Kagoshima	394	3·5	*3·3*	6·1	9·1	9·6	**13·9**	11·2	*7·4*	**8·7**	5·1	3·7	3·5	84·7
Kochi	138	*2·2*	3·6	7·4	12·3	12·1	**13·9**	13·0	*10·6*	**15·7**	9·5	4·9	3·2	108·5
Okayama	20	1·5	1·6	3·2	4·0	4·4	5·8	**6·4**	*3·8*	**5·5**	3·7	2·2	*1·4*	43·8
Tokio	69	*2·0*	2·6	4·3	5·3	5·9	**6·3**	5·6	*4·6*	**7·5**	7·2	4·3	2·3	57·9
Ishinomaki	148	*1·5*	1·9	2·9	3·7	4·1	4·5	**5·9**	*5·1*	**6·9**	5·0	2·3	2·0	45·7
Kanazawa	95	10·8	6·8	6·2	6·7	*6·1*	6·6	8·2	7·1	**8·8**	*7·5*	10·5	**14·4**	99·7
Akita	20	4·5	*3·9*	4·2	4·5	4·4	6·0	**8·1**	7·7	7·5	6·6	7·0	7·0	71·4
Hakodate	10	2·2	*2·2*	2·6	2·8	3·2	3·6	5·0	5·2	**6·7**	4·6	3·7	3·0	44·7
SOUTH-EAST ASIA AND THE EAST INDIES														
Penang	23	3·9	*3·0*	4·7	7·0	**11·0**	*7·2*	8·9	12·8	**19·0**	16·1	10·9	4·8	109·3
Singapore	10	8·5	*6·1*	6·5	6·9	7·2	6·7	6·8	8·5	7·1	8·2	10·0	**10·4**	92·9
Sandakan (Brit. N. Borneo)	98	**19·4**	9·9	7·8	*4·1*	5·1	8·6	**10·0**	*6·9*	9·5	10·2	16·4	19·3	127·2
Batavia	23	13·0	**13·6**	7·8	4·8	3·7	3·6	2·6	*1·3*	2·6	4·1	5·0	8·7	70·9
Amboina (Moluccas)	40	5·6	4·5	5·4	10·9	20·5	**23·9**	23·2	16·0	9·1	6·9	*4·1*	5·7	135·8
SOUTH-WEST ASIA														
Smyrna	66	2·8	2·6	3·2	1·1	0·9	0·4	*0*	0·4	0·5	0·8	3·4	**3·7**	19·8
Sivas	4,200	2·1	1·7	1·4	2·3	**3·0**	1·1	0·4	*0·1*	0·7	1·2	1·9	0·9	16·9
Jerusalem	2,460	**6·3**	4·6	3·5	1·5	0·3	0	*0*	0	0	0·4	2·5	5·7	24·8
Aden	94	0·3	0·2	**0·7**	0·3	0·2	0	*0*	0·1	0·2	0	0·1	0·1	2·3
Mosul	870	2·8	**2·9**	2·4	2·4	0·5	0	*0*	0	0	0·6	2·8	2·2	16·7
Bagdad	220	1·1	1·1	**1·2**	0·8	0·2	0	0	*0*	0	0·1	0·8	1·2	6·6
Teheran	3,800	1·6	1·0	**1·9**	1·4	0·5	0·1	0·2	*0*	0·1	0·3	1·0	1·3	9·3
Quetta	5,500	2·1	**2·1**	1·8	1·1	0·3	*0·2*	0·5	**0·6**	0·1	*0·1*	0·3	0·8	10·0
THE HEART OF ASIA														
Kashgar	4,255	0·3	0	0·2	0·2	**0·8**	0·4	*0·3*	**0·7**	0·3	0	*0*	0·2	3·5

MEAN RAINFALL (inches), *continued*

RUSSIAN EMPIRE

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Petrograd	30	0·9	*0·8*	0·9	0·9	1·7	1·8	2·7	**2·7**	2·0	1·7	1·4	1·2	18·8
Riga	50	1·3	*0·9*	1·0	1·1	1·7	2·3	**3·0**	2·7	2·1	2·1	1·9	1·3	21·3
Archangel	50	0·8	*0·7*	0·8	0·7	1·0	1·5	**2·2**	2·1	2·0	1·5	1·1	0·8	15·3
Kola	33	0·3	0·3	*0·2*	0·3	0·6	0·7	**1·4**	1·3	1·0	0·8	0·6	0·3	7·8
Moscow	480	1·1	*0·9*	1·2	1·5	1·9	2·0	2·8	**2·9**	2·2	1·4	1·6	1·5	21·0
Kasan	250	0·5	*0·4*	0·6	0·9	1·6	2·2	**2·4**	2·4	1·6	1·1	1·0	0·7	15·4
Warsaw	390	1·2	*1·1*	1·3	1·5	1·9	2·7	3·0	**3·1**	1·9	1·7	1·5	1·4	22·3
Kiev	590	1·1	*0·8*	1·5	1·7	1·7	2·4	**3·0**	2·4	1·7	1·7	1·5	1·5	21·1
Simferopol	853	1·2	*1·1*	1·4	1·3	1·5	**2·2**	2·0	1·3	1·5	1·1	1·3	1·6	17·5
Saratov	295	0·9	0·8	*0·7*	1·1	1·1	1·5	**1·7**	1·3	1·2	1·5	1·4	1·6	14·9
Orenburg	360	1·1	*0·8*	1·0	0·9	1·4	**2·0**	1·7	1·3	1·3	1·2	1·2	1·2	15·2
Odessa	210	0·9	*0·7*	1·1	1·1	1·3	**2·3**	2·1	1·2	1·4	*1·1*	**1·6**	1·3	16·1
Astrakhan	−50	0·5	*0·3*	0·4	0·5	0·6	**0·7**	0·5	0·5	0·5	0·4	0·4	0·5	5·9
Yalta	135	1·8	1·6	1·6	1·3	1·1	1·5	1·3	*0·9*	1·4	1·7	2·6	**3·0**	19·9
Batum	30	10·2	6·0	6·2	5·0	*2·8*	5·9	6·0	8·2	11·9	8·8	**12·2**	10·0	93·3
Baku	0	**1·3**	0·9	0·8	0·8	0·6	0·3	*0·2*	0·2	0·8	1·2	1·2	1·2	9·5
Tiflis	1,350	*0·6*	0·8	1·1	2·1	**2·9**	2·7	2·1	1·6	2·0	1·3	1·1	0·8	19·1
Kars	5,725	*0·7*	0·7	1·1	1·7	**2·7**	1·9	1·7	1·3	1·1	1·3	1·2	0·8	16·3
Krasnovodsk	−66	*0·5*	0·6	0·7	**1·0**	0·5	0·6	*0·2*	0·3	0·3	0·5	**0·6**	0·5	6·3
Petro-Alexandrowsk	295	0·2	0·4	0·5	**0·6**	0·2	0	*0*	0·1	0	0·1	0·1	0·1	2·4
Merv	755	1·8	1·4	**2·1**	1·2	0·1	0	*0*	0	0	0·4	0·1	0·4	7·5
Tashkent	1,610	1·8	1·4	**2·6**	2·6	1·1	0·5	0·1	*0·1*	0·2	1·1	1·4	1·7	14·6
Irgis	360	0·6	*0·3*	0·5	0·7	0·8	**0·9**	0·6	0·4	0·5	0·5	0·4	0·7	6·9
Semipalatinsk	590	0·5	*0·2*	0·4	0·4	0·8	0·9	**1·1**	0·4	0·6	0·6	0·6	0·8	7·3
Barnaul	480	0·3	*0·2*	0·3	0·4	1·0	1·4	**1·8**	1·6	0·9	0·9	0·7	0·6	10·1
Tobolsk	340	0·7	*0·6*	0·7	0·8	1·3	2·7	**3·5**	3·2	1·5	1·4	1·3	0·9	18·6
Beresov	100	1·0	0·6	0·8	1·3	1·6	2·2	**3·4**	2·3	2·3	1·1	1·3	*0·5*	18·4
Tomsk	390	1·1	0·8	0·8	*0·7*	1·5	2·7	**3·0**	2·3	1·4	2·4	1·4	1·9	19·9
Irkutsk	1,610	0·6	0·5	*0·4*	0·6	1·2	2·3	**2·9**	2·4	1·6	0·7	0·6	0·8	14·5
Yakutsk	330	0·9	*0·2*	0·4	0·6	1·1	2·1	1·7	**2·6**	1·2	1·4	0·6	0·9	13·7
Verkhoyansk	330	0·2	0·1	*0*	0·1	0·2	0·5	**1·2**	0·9	0·2	0·2	0·2	0·2	3·9
Okhotsk	30	0·1	*0·1*	0·1	0·2	0·5	1·1	0·5	1·8	**2·1**	0·7	0·2	0·2	7·5
Vladivostok	50	*0·1*	0·2	0·3	1·2	1·3	1·5	2·2	**3·5**	2·4	1·6	0·5	0·2	14·7

PART IV

EUROPE (EXCLUDING RUSSIA)

CHAPTER XXVIII

GENERAL FEATURES

Europe is essentially a peninsula of Asia, wide in the east, narrowing towards the west. North of the main peninsula, which includes Russia and Central Europe, are Scandinavia and Jutland, which may be considered as secondary peninsulas, and the island group of Britain; similarly Spain, Italy, and Greece are secondary peninsulas on the south.

We may look at the matter from the other point of view, and note how the seas work their way far into the land, dividing it up, and saving Europe from the curse of aridity. On the north the North Sea and the Baltic are continued by the Gulfs of Bothnia and Finland, while the White Sea extends south-west from the Arctic as if striving to make a continuous waterway to the Gulf of Finland, over the great lakes of north-west Russia. In the Mediterranean Sea with its annexes, the Adriatic and the Aegean, the Black Sea, and the Caspian, South Europe has an equally valuable series of enclosed seas to ameliorate its climate.

The seas are not only extensive, but are also remarkably warm for the latitude, since the waters of the hot Gulf Stream are wafted across the Atlantic by the prevailing westerlies, and are still so warm when they impinge on our coasts that the winters are extremely mild.

The absence of a mountain range along the west coast is another fact to which Europe owes great climatic advantages. Such a barrier exists in North America, with the result that the mountains themselves near the ocean receive a superfluity of rainfall from the westerlies, for which man can find little use, while the country to leeward suffers from aridity and great extremes

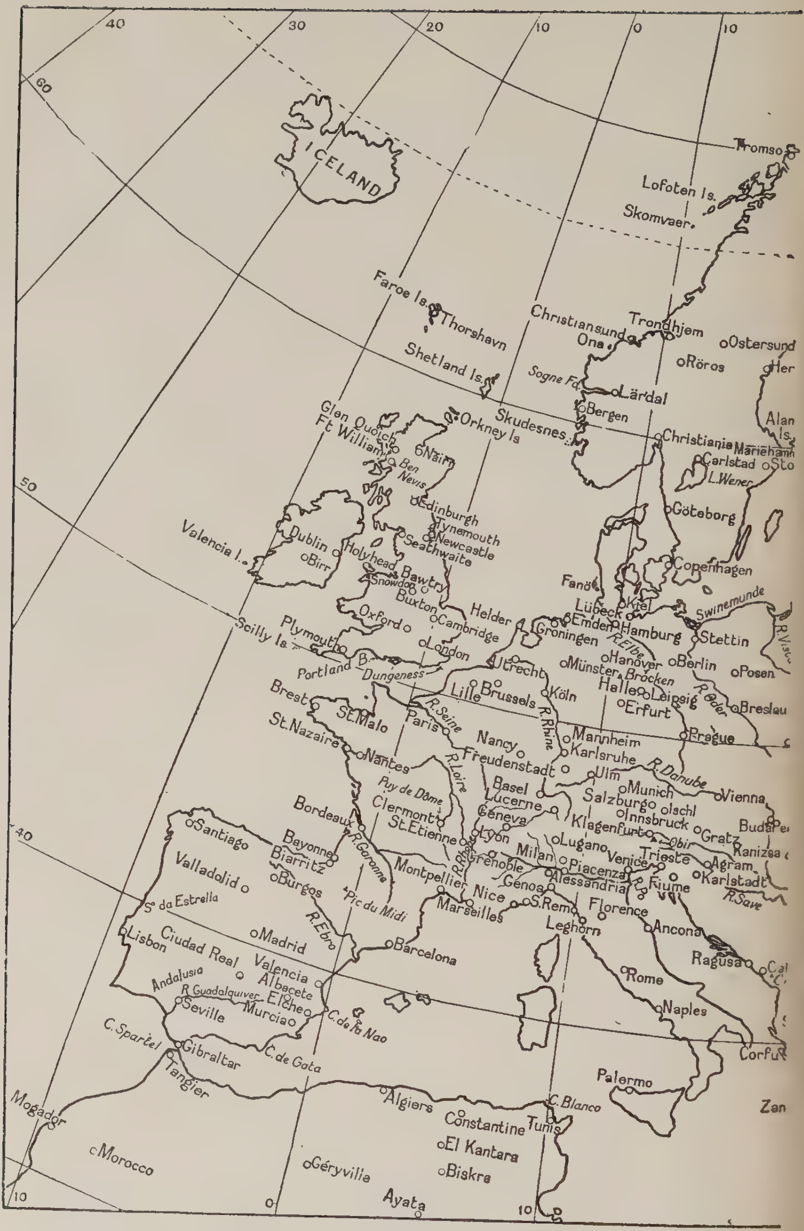
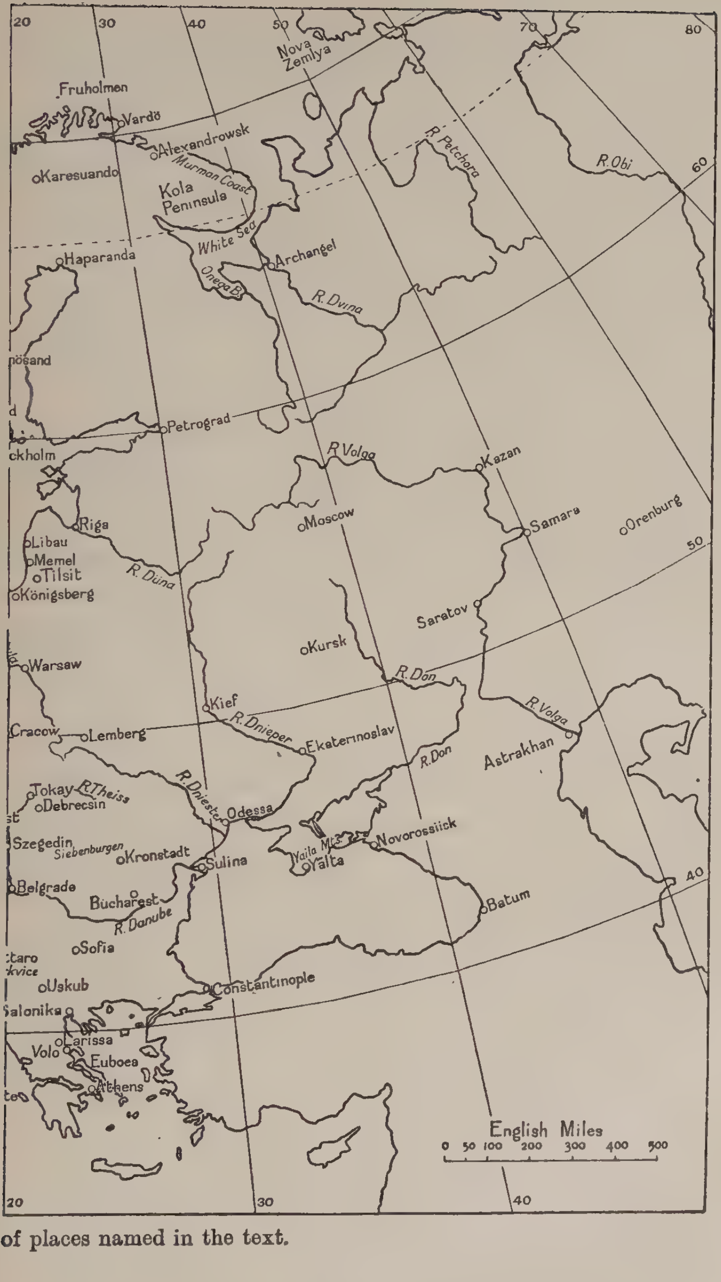

40
30
20
10
0
10
60
50
40
ICELAND
Tromso
Lofoten Is.
Skomvaer
Faroe Is.
Thorshavn
Christiansund
Ona
Trondhjem
Ostersund
Röros
Shetland Is.
Sogne Fd.
Lärdal
Bergen
Skudesnes
Orkney Is
Christiania
Mariehamn
Alan Is.
Carlstad
L.Wener
Göteborg
Glen Quoich
Ft William
Nairn
Ben Nevis
Edinburgh
Tynemouth
Newcastle
Seathwaite
Valencia I.
Dublin
Birr
Holyhead
Snowdon
Bawtry
Buxton
Copenhagen
Fanö
Lübeck
Kiel
Swinemunde
Emden
Hamburg
Stettin
Helder
Groningen
R.Elbe
Oxford
Cambridge
London
Scilly Is
Plymouth
Portland
B.
Dungeness
Utrecht
Münster
Hanover
Brocken
Berlin
Posen
R.Oder
Halle
Leipsig
Breslau
Lille
Brussels
Köln
Erfurt
Brest
St.Malo
Paris
R.Seine
R.Rhine
Prague
St.Nazaire
Nantes
Nancy
Mannheim
Karlsruhe
Freudenstadt
R.Loire
R.Danube
Ulm
Munich
Vienna
Puy de Dôme
Basel
Lucerne
Salzburg
Ischl
Innsbruck
Clermont
Geneva
Bordeaux
St.Etienne
Klagenfurt
Obir
Gratz
Buda
Santiago
Bayonne
Biarritz
R.Garonne
Lyon
Lugano
Milan
Venice
Trieste
Agram
Ranizsa
Valladolid
Burgos
Grenoble
Piacenza
Fiume
Karlstadt
Montpellier
Genoa
Alessandria
R.Save
S. da Estrella
Pic du Midi
Nice
S.Remo
Florence
Marseilles
R.Ebro
Leghorn
Ancona
Lisbon
Ciudad Real
Madrid
Barcelona
Ragusa
Valencia
Albacete
Rome
Andalusia
R.Guadalquiver
Elche
Seville
Murcia
Naples
C.de la Nao
C.Spartel
Gibraltar
C.de Gata
Corfu
Tangier
Palermo
Mogador
Algiers
C.Blanco
Zan
Constantine
Tunis
Morocco
El Kantara
Géryvilla
Biskra
Ayata
10
0
10

FIG. 74. Key map, showing the position


20
30
40
50
70
80
Nova Zemlya
Fruholmen
Vardö
Alexandrowsk
Murman Coast
Kola Peninsula
Karesuando
White Sea
Archangel
Onega B.
Haparanda
R. Petchora
R. Obi
60
R. Dvina
nösand
d
Petrograd
ckholm
R. Volga
Kazan
Moscow
Samara
Orenburg
50
Riga
Libau
Memel
Tilsit
Königsberg
R. Düna
Saratov
Kursk
R. Don
Warsaw
Kief
R. Volga
Cracow
Lemberg
R. Dnieper
Ekaterinoslav
Astrakhan
R. Don
Tokay
R. Theiss
Debrecsin
R. Dniester
Odessa
st
Szegedin
Siebenburgen
Kronstadt
Sulina
Yaila Mts
Yalta
Novorossiisk
40
Belgrade
Bucharest
R. Danube
Batum
Sofia
taro
kvice
Uskub
Constantinople
Salonika
Larissa
Volo
Euboea
Athens
te
English Miles
0 50 100 200 300 400 500
20
30
40

of places named in the text.

of temperature. In Europe the most accentuated lines of relief, the Pyrenees, the Alps, the Carpathians, and the Caucasus have a west–east trend, and on crossing them we find in many parts a sudden transition from the Central European climate to the Mediterranean. There are, it is true, isolated groups of mountains facing the westerlies on the stormy sea-boards of the British Isles and Norway; but though these cause a great local increase in rainfall, they are not sufficiently high and continuous to bring about a serious deficiency of rainfall, or very extreme temperatures, in their lee. As a result it is exceptional to find sharp climate changes in going from west to east; there is a gradual transition from the oceanic sea-board to the continental east, and such climatic boundaries as we choose to draw are generally arbitrary.

The ubiquity and warmth of the sea, then, and the trend of the main feature lines give Europe a remarkably favourable climate, with very mild winters, warm but not too hot summers, very small range of temperature for the latitude, and abundant and well-distributed rainfall. In proportion to its size, Europe has a far larger area with a climate which may be described as thoroughly suitable for the highest human development than any other continent, and even if we include Russia, we find only one small tract of useless arid desert, that lying north of the Caspian Sea; the cold tundra fringe in the north is but narrow. Many useful crops flourish in considerably higher latitudes in Europe than elsewhere. Of the ordinary products of temperate latitudes, barley is profitably grown beyond 70° N. in Norway, and rye almost as far north in Sweden. Wheat and the vine have their farthest poleward extension in Europe. Subtropical fruits find unusually favourable conditions in the Mediterranean lands. The orange and the lemon grow there even beyond lat. 44° N., and the groves of date-palms at Elche in south-east Spain are famous. Nowhere else do these fruits ripen so far from the Equator.

Pressure. The main movements of the atmosphere are dominated by three great pressure systems, the Icelandic low pressures, the Azores high pressures, and the alternating high and low pressures, of winter and summer respectively, over Asia (Figs. 4 and 31). The Icelandic low-pressure system is one of the great ‘ permanent cyclones ’ into which the planetary belts of low pressure round latitudes 60° N. and S. are broken up by the juxtaposition of ocean and continent. It is particularly deep in winter, and the baric gradients are then especially steep. It is the scene of numerous deep depressions, which advance, sometimes slowly, sometimes quickly, usually from south-west to north-east (Fig. 75). Most of them originate in North America or over the western part of the Atlantic Ocean, and some of them travel right round the globe. But they are generally deepest while passing south of Iceland, where consequently the mean barometric pressure is lowest. A tongue of low pressure projects to the north-east beyond the north of Norway, the significance of which will be pointed out later. The depressions are the immediate cause of most of the storms of wind and rain in North and Central Europe. Stormy at all times, the seas to the north-west of Europe are in winter one of the wildest regions on the face of the Earth. The main cause of the intensification of the low pressures over the North Atlantic is doubtless the great temperature difference between that region and the interior of Asia. The air tends to collect over the cold land mass; the low pressures over the North Atlantic find their complement in the high pressures over Asia.

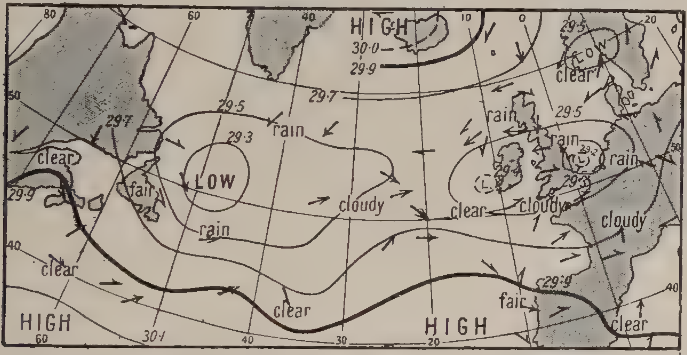

80
60
40
HIGH
30·0
29·9
10
0
29·5
LOW
clear
20
50
29·7
29·7
29·5
29·3
rain
rain
29·5
rain
29·2
rain
clear
29·9
LOW
fair
cloudy
clear
cloudy
29·4
29·3
cloudy
rain
40
clear
29·9
fair
clear
HIGH
30·1
clear
HIGH
clear
40
60
40
30
20
50

FIG. 75. Irregularities of Pressure over the North Atlantic, 7 a.m., August 26, 1912. (Weekly Weather Report, Meteorological Committee.)

In summer, the low-pressure system still persists over the Icelandic region, but its intensity is less and the surrounding gradients are very much weaker than in winter, and the cyclones which pass from west to east, are neither so numerous nor so violent. The percentage frequency of cyclones over the

North Atlantic month by month has been found by Angot to be:

Jan.	20	Apr.	5	July	2	Oct.	6
Feb.	17	May	2	Aug.	3	Nov.	13
Mar.	11	June	2	Sept.	2	Dec.	17

The high-pressure system which is centred in the neighbourhood of the Azores belongs to the subtropical high-pressure belt of the north hemisphere. The pressure is highest in summer, and the centre of the system is then farthest north, about lat. 35°. It appears on the isobar maps as a great stationary anticyclone, covering not only the Atlantic Ocean, but extending far over West and Central Europe, and the west of the Mediterranean Sea. The intensity of the anticyclone in summer is doubtless due to the fact that the great land masses are then hot, and cause the normal subtropical belt of high pressure to be replaced over them by the low pressures which give rise to the summer monsoon. The air which is unable to remain over the heated continents collects over the cooler Atlantic and Pacific Oceans, where, consequently, there are extensive anticyclones.

In winter, the Azores high pressures are much less intense, and indeed they appear on the map not as a fully developed anticyclone but merely as a band of high pressure, crossing the Atlantic about lat. 30° N., and connecting the anticyclones over Asia and North America. The straight line joining the centres of the Atlantic and the Asiatic high pressures passes over the Mediterranean Sea. But that sea is warm, and the air over it is moist; consequently it tends to produce low-pressure conditions. The result is interesting. The high-pressure ‘ bridge ’ connecting the Atlantic and Asia divides, one branch following the axis of Central Europe, the other lying over North Africa, and the Mediterranean region is left between them as a ‘ lake ’ of low pressure (Fig. 4). The Black Sea and the Caspian are for the same reason regions of lower pressure than the surrounding lands. The lowest mean pressures over the Mediterranean are less than 30 inches, over the Black Sea about 30·1, and over the Caspian less than 30·2. The readings over these seas thus become higher as we approach the great Asiatic anticyclone. West-central Europe, therefore, is a region of high pressure, in both summer and winter, but the Mediterranean has high-pressure conditions in summer, low-pressure in winter. Just as the Icelandic low-pressure system is not, strictly speaking, permanent, so the North Atlantic anticyclone is liable to considerable variations from the average in respect of intensity and position, and sometimes it is temporarily replaced by low pressures.

We have already described the pressure conditions over Asia, the third of the great systems which control the climate of Europe, in the chapters on that continent. In winter, the high pressures of Asia are continued west over south Russia, Austria, the south of Germany, Switzerland, central France, and the Iberian Peninsula. In summer, Asia is a region of low pressure, but a tongue of high pressure projects from the Atlantic over the centre of Europe towards Siberia. It is of only slight intensity, but sufficient to form a 'wind-divide'. The high-pressure ridge of the centre of Europe has been called the barometric backbone of the continent; it is of fundamental importance in separating the north European climate, with its prevailing moist westerly winds and cloudy skies, from the bright Mediterranean climate, with north-east winds.

Prevailing winds. In North-west and North Europe, and also in most of Central Europe, the prevailing winds blow from the west ('variable westerlies'), south-west in winter, north-west and west in summer. Their direction is controlled by the high pressures of the Azores and the low pressures south of Iceland. In winter, the Icelandic low-pressure system extends far south, but its centre is well to the north-west of Europe, and there is an average gradient over North Europe for south-westerly winds. In summer, the Azores system spreads farther north, and the low pressures over Southern Asia exert some control, so that the prevailing winds are north-west. The strong westerly winds blow straight from the warm ocean, which is a more important source of heat to West Europe in winter than the direct rays of the sun, and are the cause of the mild, moist, cloudy climate of West and North Europe; the extension of the Icelandic low pressures in a tongue to the north-east causes the warm oceanic conditions to be carried far east over Scandinavia and north Russia.

In most of Central Europe the prevailing winds are westerly, but their force and constancy become less as we approach the high-pressure axis of the continent. They are often interrupted by spells of almost calm weather in winter under the domination of extensive anticyclones which are more frequent here than in north-west Europe. At such times the weather is abnormally cold and dry. In summer the prevailing winds are north-west, since the normal gradient is eastward, towards the low pressures of Asia.

The European countries bordering the Mediterranean have the high pressures of the 'barometric backbone' on their north throughout the year, and consequently the winds are northerly, north-east, north, or north-west according to local conditions. In summer they are strong and constant, but in winter the frequent cyclones which appear over the Mediterranean cause the winds to be more variable, and the weather to be rainy. The north coast of Africa, being south of these depressions, has prevailing westerly and south-westerly winds in winter.

It is not intended to give here an account of the climate elements of the continent as a whole, except pressure and winds, for they will be more conveniently described in the sections devoted to the separate climatic divisions. But it will be useful to glance at the general distribution of temperature, which presents many features of interest. The most notable characteristic is its great equability. Along most of the west coast of the continent the difference between the mean temperature of the warmest and coldest months is less than 20°, a remarkably small range for the latitude. The range increases towards the east, but in almost all Europe, excluding Russia, it is below 40°, and we must go as far east as central Russia to find a range of 50°, which may be regarded as the average range for countries in these latitudes.

The summer isotherms (Fig. 76) have a normal course, running generally from west to east, but bending somewhat poleward as they get farther inland. Very little of Europe has a mean temperature below 50° in July; what little there is, is mostly in Russia. Thus the barren tundra lands are of small extent. At the other extreme, very little of Europe has a mean July temperature above 80° F., the 80° isotherms enclosing only the Mediterranean peninsulas. Europe is not enervated by excessive tropical heat in summer, for though in all the Mediterranean

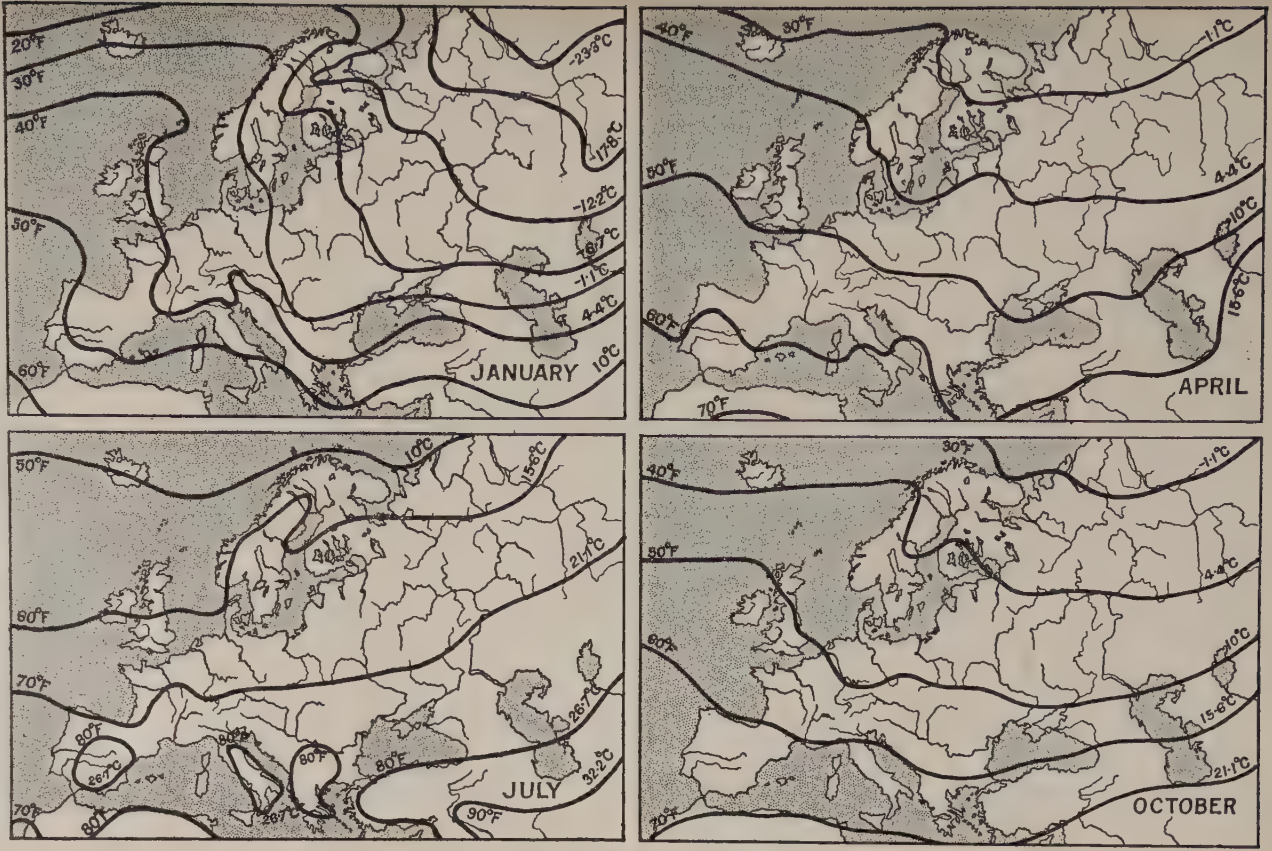

JANUARY
20°F
30°F
40°F
50°F
60°F
-23·3°C
-17·8°C
-12·2°C
-6·7°C
-1·1°C
4·4°C
10°C
APRIL
40°F
30°F
50°F
60°F
70°F
-1·1°C
4·4°C
10°C
15·6°C
JULY
50°F
60°F
70°F
80°F
90°F
10°C
15·6°C
21·1°C
26·7°C
32·2°C
OCTOBER
40°F
30°F
50°F
60°F
70°F
-1·1°C
4·4°C
10°C
15·6°C
21·1°C

Fig. 76. Temperature. (Buchan.)

lands the heat is great, the mean temperature exceeding 70° for three months, and in the south of Greece for five months, yet the air is dry and the climate healthy.

The isotherm map for January is much more striking, owing to the marked tendency of the isotherms to run from north to south. Let us follow the 40° isotherm. Running north-east over the ocean it makes a sharp curve in the neighbourhood of the Shetland Islands, and comes due south along the west of Scotland, England, and France; in the south of France it bends towards the east, reaches the head of the Adriatic Sea, and turns south and south-east again over the Balkan Peninsula to the Aegean Sea near Salonika, and then north-east to the Black Sea. In the Shetlands it is 20° of latitude north of its southernmost position over the Aegean. Equally anomalous is the course of the 30° isotherm from Iceland, far to the north-east beyond 70° N. lat., thence south-west along the Norwegian coast, and south through Jutland and Central Europe till it reaches the Danube, where it swings round to the north-east. There is a difference of almost 30° of latitude, 2,000 miles, between its extreme north and south points.

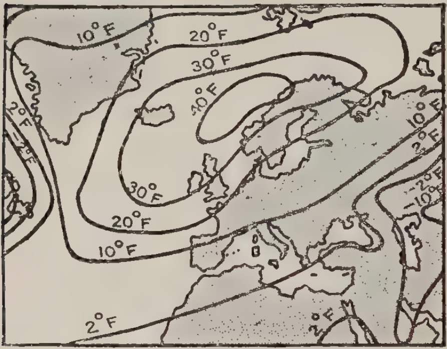


Fig. 77. Lines of equal 'anomaly of temperature' in January. The greatest excess amounts to more than 30° north-west of the British Isles.

There are two main factors involved in the north–south trend of the winter isotherms. The first is that the central core of the European peninsula is cold, like all land masses in temperate latitudes at this season; the second, that the north, and especially the north-west, of Europe is abnormally warm, and owes its heat to the warm North Atlantic Ocean from which the prevailing winds blow. The second point is much the more important. The air over the ocean, west of Norway, is more than 40° warmer than the average for the latitude, the greatest 'anomaly' (see page 3) of temperature known (Fig. 77). The high air temperature is due to the remarkably warm surface-water of the ocean; and this in turn is due to the shape of the Atlantic basin. The unusually favourable winter temperatures of North-west Europe are ultimately to be attributed to the fortunate accident that Cape St. Roque, the easternmost point of Brazil, projects into the ocean some few degrees south of the Equator, with the result that not only the north equatorial current, but also about half of the south equatorial current, are turned into the North Atlantic Ocean, at the expense of the South Atlantic. In consequence the 'Gulf Stream' is especially voluminous. The warm water is wafted on towards Europe by the prevailing westerly winds, and the wide opening into the Arctic Ocean between Europe and Iceland enables it to extend far north round Norway and along the Russian coast. The open sea in these parts is never frozen, and so presents a striking contrast to the seas north of America. Thus the advantages which result everywhere in temperate latitudes in winter from oceanic winds are specially

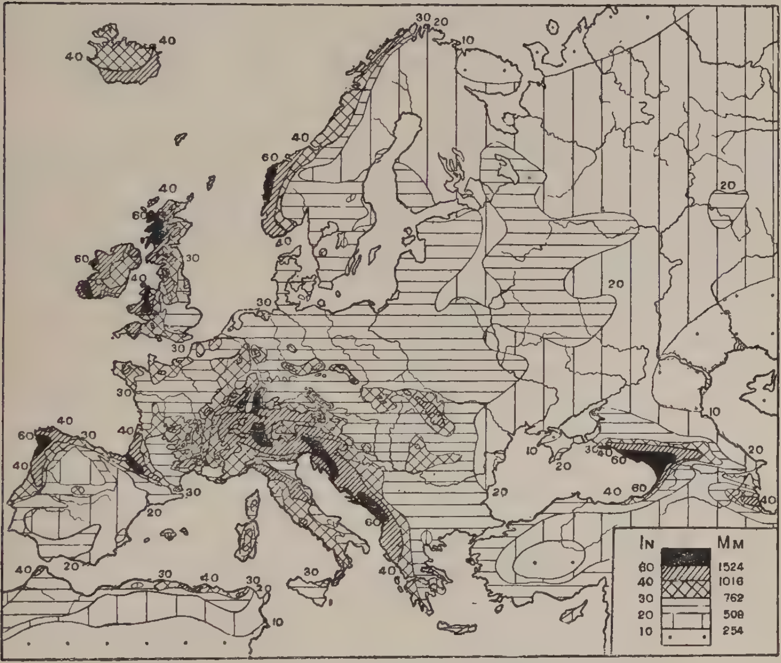


FIG. 78. Mean Annual Rainfall. (Herbertson.)

great in the case of North-west Europe. The temperatures of the Norwegian coast are considerably higher than those of the west coast of North America in the same latitude.

The coldest part of Europe in January is the extreme north-east of Russia, with a temperature below 0°. The warmest parts are the tips of the Mediterranean peninsulas, marked off by the 50° isotherm, the line which is found in the extreme north of Russia in July. The south-west of the British Isles is almost as warm as the Mediterranean countries in winter. In most of West and North-west Europe, and on the Mediterranean coasts, no month has a mean temperature below 32°; in the west of Germany the mean temperature is below 32° for one month, in the east of Germany for four months.

If on the same map the isotherms of 32° for January, and 70° for July, are drawn, Europe is divided into 4 thermal provinces, which have mean temperatures above or below 32° in January, and above or below 70° in July, respectively; these are (1) the north-west, with mild winters and cool summers, (2) the north-east, with cold winters and cool summers, (3) the south-west with mild winters and hot summers, (4) the south-east, with cold winters and hot summers.

The range of temperature increases inland, and especially towards the east, owing to the greater winter cold and, in a lesser degree, the greater summer heat. The following stations, situated in almost the same latitude, show this clearly:

		Mean Temperature °F.		
Station.	*Altitude in Feet.*	*Warmest month.*	*Coldest month.*	*Range.*
Nantes	131	66	40	26
Basel	909	66	32	34
Vienna	656	67	29	38
Debreczin	459	71	25	46

We shall constantly have occasion to refer in later chapters to these general principles, that the farther east we go the colder are the winters, and the greater is the range of temperature.

Figs. 78 and 79 show the distribution of rainfall.

The continent may be divided into four major climate regions (Fig. 80). East Europe has been described already (Chap. xxvii). We now proceed to consider the other three.

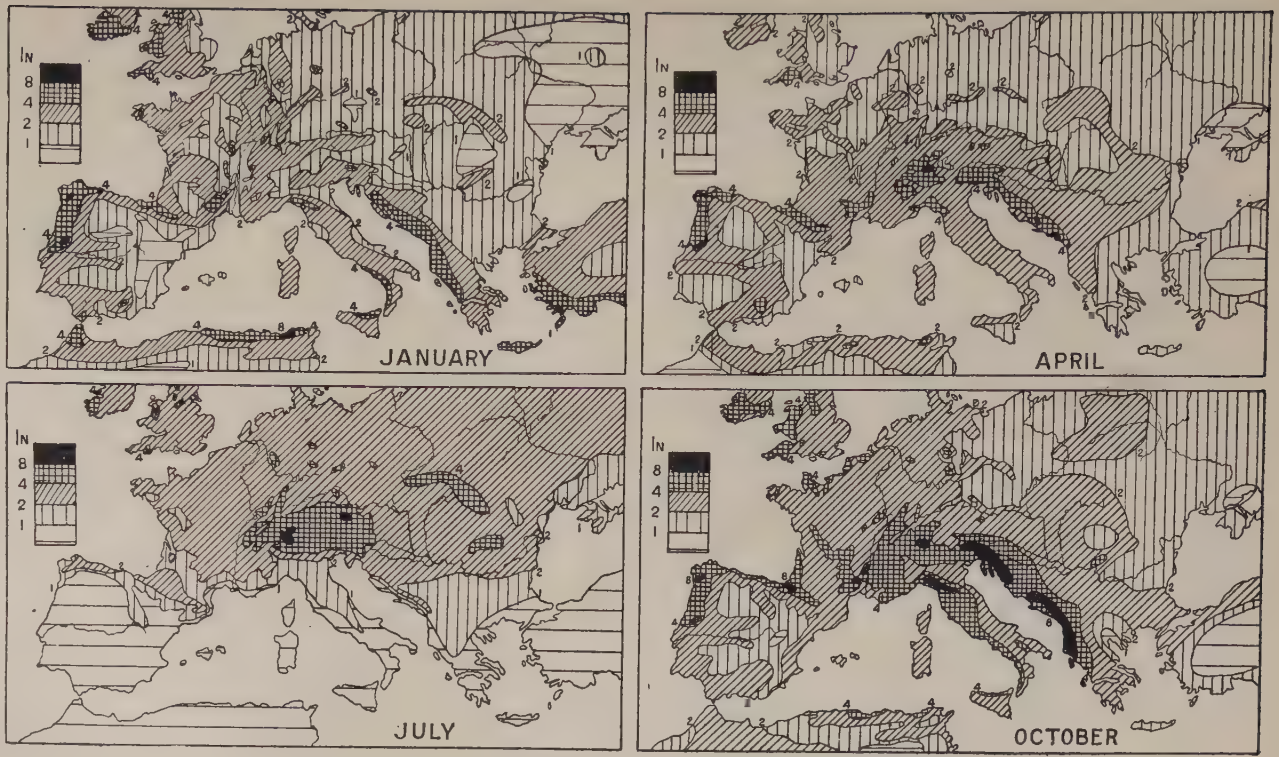

IN
8
4
2
1
JANUARY
APRIL
JULY
OCTOBER

Fig. 79. Mean Rainfall. (Herbertson.)

CHAPTER XXIX

NORTH-WEST EUROPE

The prevailing winds in winter are south-west, not only in North-west Europe but also in north Russia, owing to the tongue-like extension of the Icelandic low-pressure system to the north-east. The almost constant strong winds, and frequent gales, that rage round the coasts, have already been mentioned; their fury is unfavourable to tree growth, and on the most exposed islands, such as the Orkneys and Färoe Islands, there are no trees at all except where artificial shelter is provided.

Temperature. We have considered in the last chapter one of the most important of the physical facts to which Western Europe owes its open winters, the main peculiarity of its climate. That fact is the remarkable warmth of the surface water of the North Atlantic Ocean. We have seen that the mean air temperature in January over the ocean west of Norway is more than 40° warmer than the average for the latitude. The excess becomes less towards the east, and in central Russia the continental deficit begins. The mean temperature in January at Thorshavn, Färoe Islands, is 38°, and severe frost is unknown; at Yakutsk, in the same latitude in eastern Siberia, the mean is –46°. Comparing the temperature on the east and west shores of the Atlantic, we find a mean of 39° in January in the Orkney Islands, –21° at Hebron, Labrador, in the same latitude. The open sea on the north-west and most of the north of Europe is never frozen, even in the severest winters.

The mean January temperature in North-west Europe is above (or only very little below) 32° F.; in Spain, the warmest part of the continent, it exceeds 50°; in the west of France and the British Isles, it exceeds 40°. The 32° isotherm for January skirts the coasts of Norway and Jutland; its abnormal course shows that the temperature decrease is from west to east, rather than from south to north; the south-west of Ireland has the same mean temperature as Nice and Rome. It becomes rapidly colder towards the east. At Brest, the mean January temperature is 43°, at Paris 36°, so that a journey of 310 miles away from the coast brings us to a climate 7° colder. Indeed Paris is colder than Thorshavn, which is 850 miles nearer the Pole. The west coast of the British Isles is warmer than the interior and the east coast; the January mean at Valencia is 45°, at London 39°. The phenomenon is more marked in Norway (Fig. 81); the heads of the longest fiords are as much as 10° colder than the open coasts, and their farthest recesses are often frozen over for some time in winter; but on the open coast, ice is unknown, even

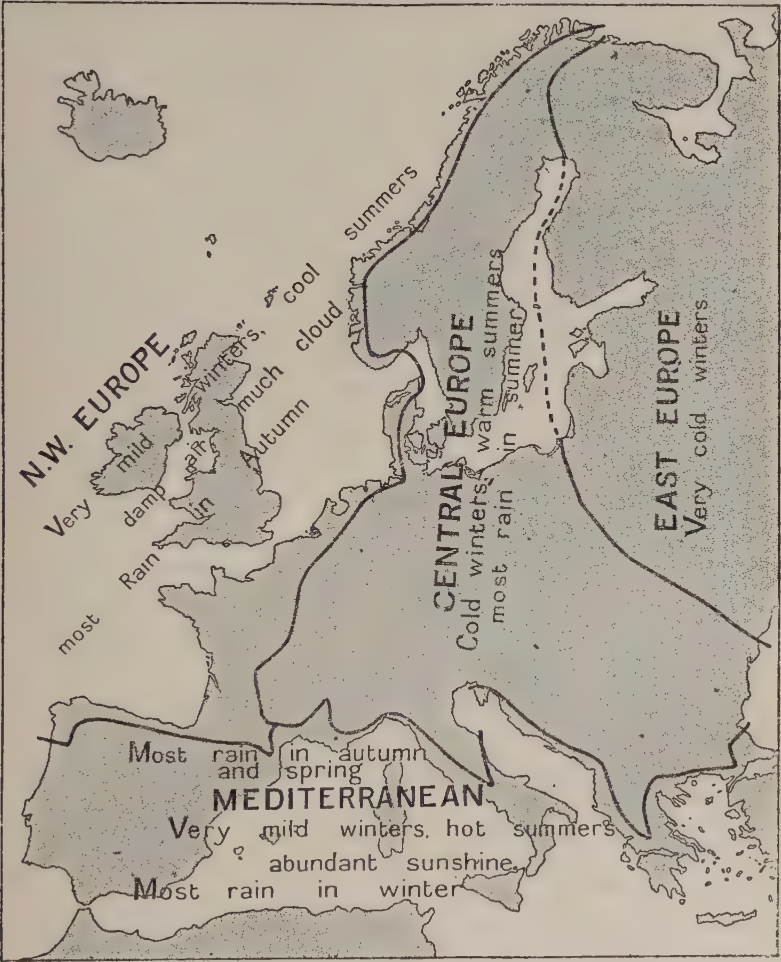

N.W. EUROPE
Very mild winters, cool summers
damp air much cloud
most Rain in Autumn
CENTRAL EUROPE
Cold winters; warm summers
most rain in summer
EAST EUROPE
Very cold winters
Most rain in autumn and spring
MEDITERRANEAN
Very mild winters, hot summers
abundant sunshine
Most rain in winter

FIG. 80. The major climate regions of Europe.

beyond the Arctic circle. The mean January temperature is 34° at Bergen, 24° at Christiania, which has comparatively severe winters, with a mean temperature below 32° for four months, since it is at the head of a fiord, which runs far into the land, and is in the lee of the land mass of Norway; Christiansund, on the open west coast of Norway, is warmer than Hamburg, which is about 700 miles farther south, but some distance up the estuary of the Elbe.

No month of the year has a mean temperature below 32°, except the northern part of the west coast of Norway. Here the duration of the cold period increases rapidly as we go north, and on the coast inside the Arctic circle we find four months with a mean temperature below, but only a little below, freezing-point.

With regard to the lowest temperatures that occur, on the west coast of Spain frost even at night is the exception, and on the extreme west coasts of France and the British Isles frost is rare. At Paris frost must be expected on half the nights during the three winter months. In the neighbourhood of London, the thermometer remains above freezing-point on January nights rather more often than it falls below it; the temperature is very rarely below 15°. On the coast of Norway frost is more frequent, but is very rarely severe except in the north. The lowest readings that have been recorded are:

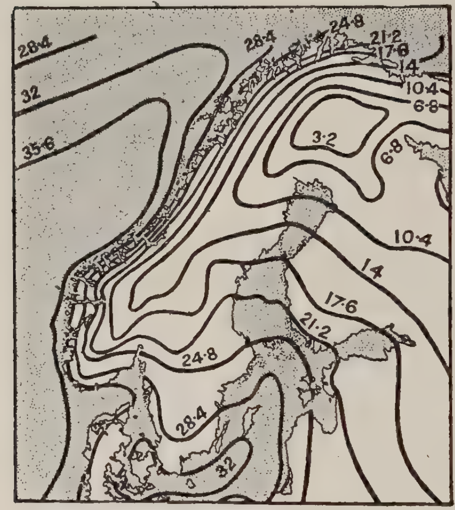


Fig. 81. Mean Temperature in January over Scandinavia. (Hann.)

Paris	−11°
Kew (London)	9°
Valencia	20°
Scilly Isles	25°

The mildness of the winters of the south-west coasts of the British Isles and the west coast of Brittany finds expression in the vegetation. The strawberry tree (arbutus) flourishes in the woods of Killarney, the myrtle, fuchsia, and laurel grow well, and even the lemon tree will live, given a little shelter, in Devonshire, recalling the flora of the Mediterranean lands. Snow is sufficiently rare in most of north-west Europe to be a topic of conversation when it lies more than a few days, but in the more mountainous parts it is abundant.

The summers are cool. The coasts are cooler than the interior, which shows that at this season the sea is a cooling agent, in spite of the North Atlantic Drift. But the interior is not nearly so much warmer than the coasts in summer as it is colder in winter; the mean July temperature at Paris is only slightly higher than at Brest, and London is only 4° warmer than Valencia. The highest temperature ever recorded at Paris is 100°; Greenwich has the same record.

Autumn is warm as compared with spring, a common feature of a maritime climate; the mean temperature at Valencia in April is 48°, and in October 51°.

Rainfall (Figs. 78 and 79). The rainfall is everywhere abundant, and in the mountains excessive, in all seasons. The driest parts are the Paris and Garonne basins, the Low Countries and north Germany, and the east of the British Isles, with from 20 to 30 inches of rain a year. Even low hills have a heavier rainfall than the plains; and the Pyrenees, the Central Plateau of France, the Highlands of Brittany, show their influence very clearly on the rainfall map. But especially great is the rainfall of the rugged western seaboard of the British Isles, notably in south-west Ireland, the Highlands of Scotland, the Lake District, and the Welsh mountains. The last has the heaviest rainfall in North-west Europe; it is one of the heaviest in the whole continent, and takes a high place among the rainfall totals of the world. At Styehead Pass, Cumberland, the mean is 170 inches in the year, and round Snowdon as much as 200 inches. There is an extraordinarily rapid diminution from west to east in the British Isles; Ben Nevis receives 171 inches in the year; Nairn, 70 miles to the east, only 25 inches. Similarly in Norway, at Bergen the rainfall is 73 inches, while at the head of the Sogne Fiord, 80 miles from the open coast, it is only 30 inches.

The copious rainfall of the west coasts is due to the mountains which rise in the course of the prevailing westerlies. The warm sea over which the winds have blown has provided an abundant store of moisture, which the frequent cyclones assist in condensing. Fortunately the mountain barrier is neither so high nor so continuous that the lowlands beyond are in danger of drought.

The rainfall shows no strongly marked periodicity, being abundant in all seasons. But in most of North-west Europe spring is the driest season. Autumn is the wettest, since cyclones are then most numerous and active, and the sea is warmest relatively to the land. We must now consider the rainfall régimes in more detail. At Thorshavn (see p. 216), we have a pure oceanic régime; the winter half-year is rainiest with 63 per cent. of the year's total; of the four seasons, winter and autumn have most rain, summer and spring least; January is the rainiest month, June the driest. These facts have evidently a close connexion with the monthly frequency of cyclones over the North Atlantic (p. 202); most rain falls in the months when cyclones are most numerous. The west coasts of Norway, the British Isles, and France (Bergen, Valencia, and Brest), have much the same rainfall curve as Thorshavn.

As soon as we leave the western seaboard there is a change, summer becoming rainier at the expense of winter. In the British Isles (Oxford, London, Edinburgh), spring is still the driest season as at Valencia, but winter has almost the same percentage of the year's total rainfall as spring. The summer maximum is greatest in the east; the excess of summer over spring at Edinburgh is equal to the excess of winter over spring in the west.

In most of the east midlands and the east coast of Great Britain, as far north as Forfar, and in the east of Ireland, the summer percentage is so increased as to become the maximum of the year; but the autumn figure follows close behind. The summer excess is greatest in East Anglia. On the east coast, north of Dundee, autumn and winter are the wettest seasons, the oceanic régime dominating the whole of north Scotland. There is little difference in the amounts of the winter and summer half-years, but it is interesting from a theoretical point of view that the summer half-year is the rainier in much of the midlands, and on the east coast except in the extreme north. Thus the east of the British Isles has a continental rather than oceanic rainfall régime.

Considering next the mean monthly rainfall, we find everywhere two maxima, one in autumn or winter, generally in October, the other in late summer, generally in August. Almost everywhere the autumn or winter maximum is the chief, and is due to the same causes that produce a mid-winter maximum on the ocean, viz. cyclonic activity and the relative excess of warmth in the sea (Valencia, Fig. 82). As autumn runs on into winter the land cools rapidly, and the cold, together with the resulting tendency to high atmospheric pressure, prevents the rainfall increasing inland beyond the October figure in spite of the increasing cyclonic activity over the ocean. The late summer monthly maximum is greatest only in a small part of the east of Great Britain and of Ireland (Cambridge, Fig. 82). This is a continental characteristic, and we shall discuss its cause more fully in considering the rainfall of Central Europe, where it is more prominent.

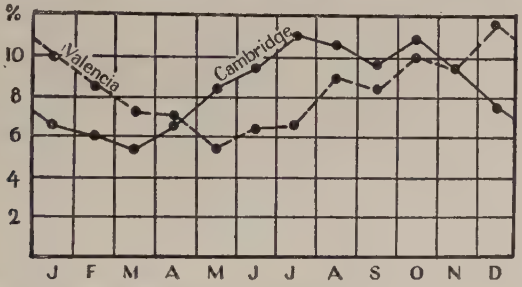


FIG. 82. Mean monthly Rainfall at Valencia and Cambridge (percentage of yearly total).

Spring is the driest season everywhere in the British Isles, April and May the driest months. The sea is then coolest relatively to the land, so that the vapour-capacity of air blowing from the sea is increased over the land and the air tends to become drier rather than to give up moisture. Moreover there is a greater tendency in spring than in other seasons for anticyclones to take up a position to the north of the British Isles, causing dry north-east and east winds.

In France there is a similar transition from the oceanic type of the west coast (Brest), with seasonal percentages much the same as in the west of Ireland, to the more continental régime of the interior and east, where there is more rain in the summer than in the winter half-year. By far the greater part of the country conforms to this latter type; the oceanic régime is found only in a narrow coastal strip. In the north interior of France (Paris) summer is slightly rainier than autumn; in the centre (Clermont-Ferrand) and east (Lyon) summer is wettest, with twice as much rain as winter. But in the more continental as in the oceanic division, October is in most places the wettest month (June at Clermont), and there is a secondary maximum in early summer, June or July. Thus the interior of France provides an interesting transition from the pure oceanic type of rainfall which is found on the west coast, with an autumn maximum, and more rain in the winter than in the summer half-year, to the continental type in which summer is the rainiest season, and the summer is rainier than the winter half-year.

Seasonal distribution of rainfall in North-west Europe (percentages of the yearly total)

	Winter.	*Spring.*	*Summer.*	*Autumn.*	*Winter Half-year.*	*Summer Half-year.*
Thorshavn .	32	20	*17*	31	63	37
Bergen . .	29	*18*	21	32	57	43
Valencia .	31	*20*	21	28	58	42
Oxford . .	24	*21*	28	27	51	49
London (Camden Sq.) .	24	*21*	27	28	52	48
Edinburgh .	22	*20*	31	27	48	52
Brest . .	29	19	*19*	33	59	41
Paris . .	*20*	23	29	28	46	54
Lyon . .	*15*	25	30	30	41	59
Clermont-Ferrand . .	*16*	26	32	26	38	62
Brussels .	22	*21*	30	27	48	52
Emden . .	22	*20*	31	27	48	52
Hamburg .	21	*22*	33	24	45	55

Passing now to the south coast of the North Sea, we find at Brussels almost exactly the same régime as at Edinburgh. Emden and Hamburg are very similar, but the summer maximum is more pronounced.

In North-west Europe, then, the oceanic type of rainfall with its maximum in winter is confined to a very narrow coastal strip (Fig. 83). As soon as we go inland we find the winters drier and the summers rainier. But we must repeat what was said at the beginning of our remarks on this subject, that there is no marked periodicity in the rainfall. There is abundant rain in all seasons. Even in the driest years serious drought is very rare. With a warm ocean lying close to windward, the air is always moist, especially in winter, and evaporation over the land is slow. It is not lack of water as in the savanna lands, but the cold of winter, that determines the resting-time for plant life.

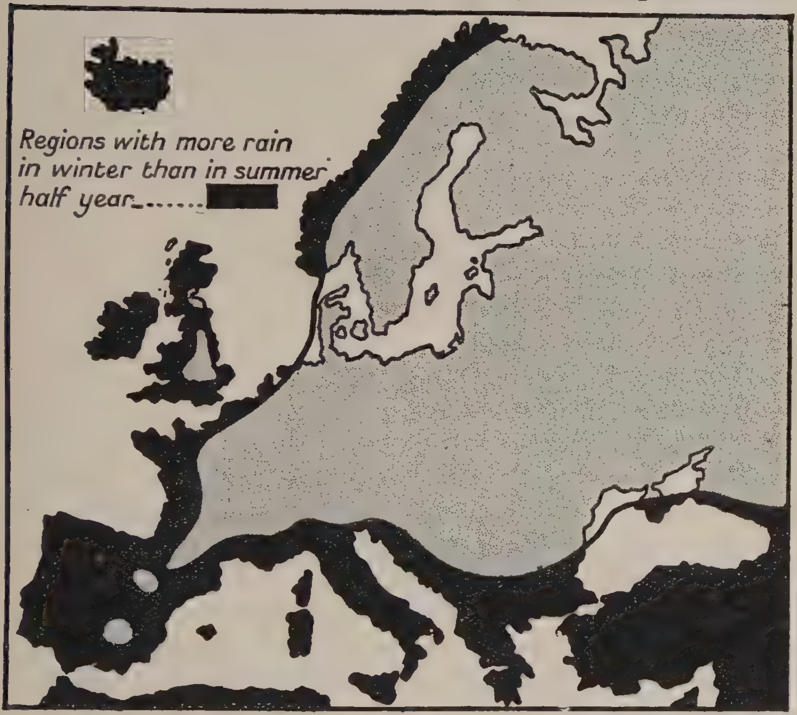

Regions with more rain in winter than in summer half year....... ■

FIG. 83.

The skies of North-west Europe are very cloudy; indeed this is one of the cloudiest regions on the earth. In the south of England, taking the average of the year, seven-tenths of the sky is clouded; in September alone the cloud covering decreases to six-tenths. Sunshine is scanty, notably in the extreme north of Scotland which projects towards the most frequented cyclone tracks of the North Atlantic, and sees the sun for only 1,200 hours in the year, and for less than an hour a day in winter. It becomes rapidly sunnier as we leave the ocean. On the south coast of

England, the mean annual total is 1,700 hours, but even this record represents a land of dull skies. We have already mentioned that the winters of the south-west of Ireland are as mild as those of Italy. But the sunshine records warn us against attempting to put the two places in the same climate category. For at Valencia there are only 1,442 hours of sunshine in the year, 31 per cent. of the total number of hours during which the sun is above the horizon, at Rome 2,397 hours, 55 per cent. of the total possible. North-west Europe is often cloudy and rainy and does not see the sun for days and even weeks together; but Rome is in the favoured Mediterranean region, where the rainfall may be heavy, but is usually of short duration, and there is rarely a day on which the sun does not shine.

CHAPTER XXX

CENTRAL EUROPE

Central Europe is the transition region between the oceanic north-west of Europe and continental Russia. The prevailing winds over most of the area are south-west all the year, but are neither so constant in direction nor so strong as in the north-west; and on many a winter day, while the shores of Britain are swept by gales bringing abundant rain and abnormal warmth from the western ocean, Germany is enjoying the cold, crisp, calm air of an anticyclone.

We have seen that the high-pressure belt, the 'wind-divide' of the continent, lies over the Alps; north Switzerland and all Germany have prevailing west winds, Hungary, Rumania, and the Balkan Peninsula have north and north-east winds, dry and piercing in winter as in the steppes of south Russia.

The winter temperature decreases towards the east rather than the north, as already explained. In the western half of Germany long-continued frost and snow are much less frequent than in the east where they are the usual conditions. In the case of the Scandinavian Peninsula the highland barrier which rises steeply from the west coast causes the change from oceanic to continental conditions to be accomplished in a few miles; the Norwegian coast has wonderfully mild winters, but in the interior of the peninsula the cold is severe; the east coast is warmed somewhat by the Baltic Sea, but is much colder than the west coast. We give below the mean temperatures at typical series of stations. The first series lies across the south of the peninsula: Karlstad has a higher temperature than might have been expected from its position in the interior, and this is doubtless due to the great lake Wener lying to windward. In the second series, Karesuando, which is situated on the frontier of Sweden and Russia in lat. 68½° N., is remarkably cold by comparison with Skomvaer in the extreme south of the Lofoten Islands. Haparanda, on the north shore of the Gulf of Bothnia, shows that the ice-bound sea has but little ameliorating influence, for it is only 6° warmer than Karesuando which is 1,050 feet higher.

		MEAN TEMPERATURE		
Station.	*Altitude in Feet.*	*Coldest month.* °F.	*Warmest month.* °F.	*Range.* °F.
Skudesnaes	16	34	58	24
Christiania	82	24	63	39
Karlstad	180	25	62	37
Stockholm	148	26	62	36
Skomvaer	66	31	51	20
Karesuando	1,083	5	54	49
Haparanda	33	11	59	48

The summer figures show the opposite arrangement of temperature, but the differences are not so great. On the west coast, south of Christiansund, no month has a mean temperature below 32°, but in the interior the mean monthly temperature is below 32° for 6 months of the year.

In central Germany, Austria, Hungary, and Rumania temperatures below zero occur in most winters. West Germany has 1 month, east Germany 3 months, with a mean temperature below 32°. All the rivers of Germany are frozen in part of their courses in winter. The Rhine is ice-bound at Köln for 21 days in an average winter; in the severe winter of 1829–30 no less than 220 miles out of the 270 miles between Mannheim and Holland were frozen; in December 1879, 170 miles were frozen. The Oder is frozen for 80 days on an average, the Memel at Tilsit for 134 days. Even the lower Danube is blocked by ice for 37 days. The Saône (east France) is closed to navigation for 15 days. Germany's North Sea coasts are never frozen, but ice-breakers are required to keep the harbour of Hamburg open. Her Baltic shores have more severe winters, and, though the open coast is rarely frozen, the harbours are ice-bound every year, Lübeck for 32 days, Swinemünde for 20 days, Stettin for 61 days, the inner harbour of Memel for 142 days.

In summer the interior of the continent is warmer than the coasts; the isotherms curve poleward as they cross from west to east. The limit of cultivation of the vine runs north with them to its farthest north, lat. 52°, on the Elbe; east of this the limit falls again toward the south, since, though the summers are warmer, they are too short for the grapes to ripen satisfactorily; autumn is not so warm in east as in west Europe. Spring, however, is slightly warmer in the east, the maritime influence in Western Europe checking the rise of temperature. The shores of the Baltic have especially raw-cold weather in spring. The hottest part of Central Europe in summer is Hungary and Rumania, the mean July temperature being 74° at Szegedin, 73° at Bukarest. These steppe lands are exceedingly hot on summer days.

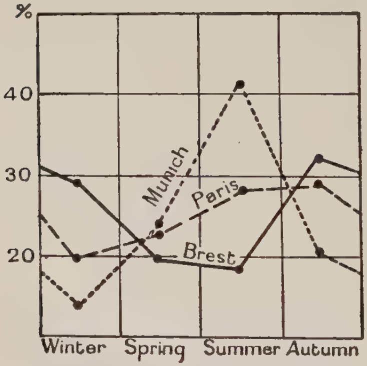


Fig. 84. Seasonal Rainfall (percentage of annual total).

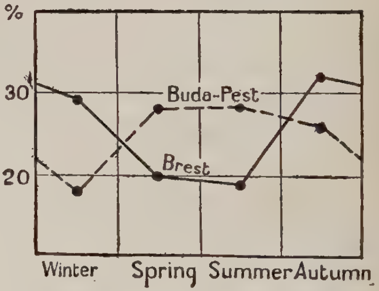


Fig. 85. Seasonal Rainfall (percentage of annual total).

The land rises on the whole from the flats on the coast of the North Sea to the foot of the Alps, and this rise neutralizes the effect on temperature of the more southern latitude in summer. Thus Berlin, 164 feet above the sea, has a mean July temperature of 65°, Munich, 1,740 feet above the sea, 63°. We shall devote a special section to the modifications introduced by the Alps.

Rainfall. The mean annual rainfall in the plains is practically the same everywhere, between 20 and 30 inches. It is well distributed over the year; summer has most, but there is no true dry season. We obtain an instructive picture of the rainfall régimes from the consideration of 'sections' of the rainfall of the continent from west to east, and from south to north. Our first section is provided by the records from the following series of stations extending from Brittany to Rumania:

	Rainfall. Percentage of Yearly Total.							
Station.	*Winter.*	*Spring.*	*Summer.*	*Autumn.*	*Winter Half-year.*	*Summer Half-year.*	*Rainiest month.*	*Driest month.*
Brest	29	19	*19*	**33**	59	41	Oct.	May
Paris	*20*	23	**29**	28	46	54	Oct., June	Feb.
Karlsruhe	*19*	23	**32**	26	44	56	June, Oct.	Feb.
Munich	*13*	24	**39**	24	31	69	June, July	Feb.
Salzburg	*14*	23	**42**	21	30	70	July	Jan.
Klagenfurt	*13*	23	**35**	29	37	63	July	Feb.
Budapest	*19*	**28**	**28**	25	43	57	May, June, Oct.	Feb.
Szegedin	*19*	26	**31**	24	42	58	June, Oct.	Feb.
Bukarest	*17*	27	**35**	21	39	61	June, Nov.	Feb.
Sulina	*19*	23	28	**30**	45	55	June, Sept.	Feb.

In Brittany most rain falls in autumn and winter—an oceanic régime. At Paris the maximum comes in summer, but autumn has almost the same percentage, and the summer half-year receives more rain than the winter half; October is the wettest month but there is a secondary maximum in June; this is typical of most of France, but in the south-east the secondary maximum is in May. Entering Germany, at Karlsruhe we find the continental régime, with a pronounced summer maximum; the rainiest month is June, but the secondary maximum in October shows that we have not yet completely lost oceanic influences. Munich and Salzburg have a more accentuated continental régime; there is no secondary maximum in October. In Austria and Hungary a new tendency appears, spring becoming more rainy at the expense of summer. In most of Hungary and Rumania more than a quarter of the rainfall is received in spring;

summer is the rainiest season, however; May and June are the rainiest months; autumn has considerably less rain than spring. At Buda-Pest the rainfall régime is the opposite of that of Brest (Figs. 84 and 85).

Our second section runs from the head of the Adriatic to the Baltic. Central Europe is bounded on the south by the Mediterranean region with rainy autumns and dry summers, represented by Fiume, which has most rain in October, least in July, and a secondary maximum in June.

	Rainfall. Percentage of Yearly Total.							
Station.	*Winter.*	*Spring.*	*Summer.*	*Autumn.*	*Winter Half-year.*	*Summer Half-year.*	*Rainiest month.*	*Driest month.*
Fiume .	*20*	23	*20*	**37**	54	46	Oct., June	July
Agram .	*16*	24	**30**	**30**	44	56	Oct., June	Feb.
Budapest .	*19*	**28**	**28**	25	43	57	May, June, Oct.	Feb.
Prague .	*13*	26	**38**	23	31	69	June	Feb.
Breslau .	*16*	24	**38**	22	36	64	July	Feb.
Berlin .	*20*	23	**33**	24	44	56	July	Feb.
Kiel .	*22*	*20*	**31**	27	48	52	July, Oct.	April

The Mediterranean régime dies out rapidly as the sea is left behind, and at Karlstad and Agram there is more rain in summer than in winter, but in all Hungary except Siebenbürgen the Mediterranean influence can be traced in the rise in the rainfall curve in October. The following table shows how October becomes relatively drier as we leave the Adriatic, and summer, especially early summer, rainier:

PERCENTAGE MONTHLY RAINFALL

Station.	*Distance in miles from Adriatic Sea.*	*January.*	*February.*	*March.*	*April.*	*May.*	*June.*	*July.*	*August.*	*September.*	*October.*	*November.*	*December.*
Fiume .	0	6	*6*	8	**9**	8	8	*4*	6	11	**15**	11	8
Karlstad .	55	5	*5*	7	8	9	**11**	*7*	9	10	**12**	10	7
Agram .	80	5	*5*	6	8	10	**11**	*9*	10	9	**12**	9	6
Kanizsa .	145	*4*	5	6	9	**11**	10	10	10	*9*	**11**	9	6
Budapest .	265	6	*5*	7	9	**12**	**11**	9	*8*	8	**10**	8	7

At Buda-Pest early summer is the rainiest season, the régime of the steppes of Hungary resembling that of south Russia (p. 188). Farther north the maximum is retarded; July is the rainiest month and spring becomes drier; but even on the south coast of the Baltic Sea (Kiel) the winter maximum of North-west Europe does not occur. In almost all Sweden the maximum comes still later, in August, and there is a slight secondary maximum in October.

Our two rainfall sections, then, illustrate the facts that in much of France away from the coasts, and in the south and west of Germany the rainiest month is June, and that the maximum is still earlier in Hungary and Rumania, where there is a marked early summer maximum as in the steppes of south Russia. February is almost everywhere the driest month, and winter is the driest season. In the interior of the continent autumn is drier than spring.

The winter minimum is the result of the high pressures which the winter cold produces over Central Europe. The cushion of dense air tends to keep at bay the cyclones which give so much rain to the coasts of North-west Europe at this season. But in summer pressure is lower, and there is not so much resistance to the advance of depressions, which, therefore, though neither so numerous nor so deep as in winter, are able to reach Central Europe. Moreover, in summer the air, being warmer, can contain more moisture than in winter, and gives more precipitation for a given amount of cooling. The ground is heated by the strong sunshine, and convectional overturnings take place between the layers of air resting on it and those above, the process often being accompanied by thunderstorms and heavy downpours of rain. In Hungary 61 per cent. of the rain in June falls on days with thunderstorms. We might naturally expect convection to be most vigorous in the hottest month, July, and it is so in north Central Europe. But in most of the region the heaviest rainfall is in June, so that surface heating alone is not sufficient explanation. The greatest convectional overturning takes place not necessarily when the lowest strata of the atmosphere are heated most, but when equilibrium is most unstable between them and the higher strata. The instability is probably greatest in the early summer during the midday hours, since the upper air has not yet been much heated, and, indeed, is but little past its minimum temperature for the year; for the free atmosphere 'lags' in temperature behind the sun even more than does the ocean. But in June the air resting on the ground is already greatly warmed. In July the lowest strata of the air are warmer, but so also are the upper strata, and convection is less active. It must also be remembered that irregularities of pressure distribution are more frequent in early summer, the season of transition from winter to summer conditions, when barometric gradients are slight, than when the summer circulation is fully established.

Though summer is the rainiest season in Central Europe, yet there, as in North-west Europe, the air is then drier than in winter, and evaporation more active, a fact which makes the seasonal distribution of moisture more uniform from the point of view of animal and plant life than the monthly rainfall means indicate. In summer, too, the sky is least cloudy, but most of Central, like North-west, Europe can be truly described as cloudy in all seasons. It is only when we cross the Alps that we leave the region of gloomy skies, and enter, quite suddenly, the bright and sunny Mediterranean world.

The Alps.

Mountains make their own climates. The Alps offer a particularly tempting field for investigation, since they are the greatest range in Europe, and excellent series of meteorological observations are available. Furthermore the region is dominated by anticyclonic conditions, under which some of the most interesting peculiarities of mountain climate occur.

Temperature. On an average the air is 1° F. cooler for every 300 feet increase of altitude. But this figure is merely a mean value, derived from very diverse elements, and it will rarely be found to hold good in practice if we take simultaneous readings at different heights on a mountain side. The actual vertical 'gradient' of temperature depends on the time of day, the season of the year, the state of the weather, and especially on the topography of the neighbourhood. In the Alpine region we have to deal with (i) such wide open plains as the Swiss Foreland, 1,200 to 2,500 feet above the sea, (ii) narrow valleys, deep and steep-sided ravines between some of the highest summits in Europe, with climatic peculiarities according as they open to the north or the south, the east or the west, (iii) upland valleys, (iv) the mountain summits.

In many cases the nature of the topography has a more profound influence than the absolute altitude of the station. Let us examine the mean temperatures at Lucerne, situated almost on the Swiss Foreland, the Rigikulm, an isolated mountain summit overlooking Lucerne from some 4,500 feet above, and Bevers, a station in the valley-bottom of the Upper Engadine, a deep trench bounded by lofty mountain ranges; its altitude is approximately the same as that of the summit of the Rigi, but the topography is in complete contrast.

TEMPERATURE, °F.

		July.			*January.*			*Range.*
Station.	*Alt. Feet.*	*Mean daily.*	7 a.m.	1 p.m.	*Mean daily.*	7 a.m.	1 p.m.	*July–Jan.*
Lucerne .	1,480	65	62	71	30	27	32	35
Rigikulm .	5,860	50	49	52	24	22	25	26
Bevers .	5,610	53	48	62	14	8	22	39
Difference,								
Lucerne–Rigi		15	13	19	6	5	7	
Rigi–Bevers		−3	1	−10	10	14	3	

The atmosphere is heated in the daytime in two ways, by the passage through it of the direct rays of the sun, and by conduction from the earth which is heated by those rays. Pure air is unable to absorb much of the sun's heat directly, but the presence of dust and moisture particles increases the absorption greatly, and as dust and moisture are most abundant in the lowest layers those layers are most heated. But the second way is much more effective, and the heat will be greatest in valley-bottoms where the air rests on concave slopes which provide the greatest area of contact. The pointed summits and convex slopes of highlands, on the other hand, present but small areas as sources of heat to the air around them. The movement of the air is another factor. At the higher levels there is usually a strong wind, and the air cannot be warmed so much during its short contact with the warm rocks as the calmer strata below. The nocturnal cooling of the air is due chiefly to contact with the ground which loses its heat through radiation into space, and therefore the concave valleys will be as effective in cooling the air at night as in warming it by day. Moreover, cool air is denser than warm;

the coldest air tends to drain downwards from all the slopes around and to collect in the bottoms, where it forms stagnant ‘ lakes ’, in which the temperature is sometimes lower than on the mountain tops. Such ‘ inversions of temperature ’ are most frequent during calm anticyclonic weather. It is true that owing to the clearer and less dense blanket of air the sun’s rays at great elevations are very powerful, and the rocks on the mountain tops become very hot by day ; they also lose their heat very rapidly at night. But the other influences outweigh this in controlling the shade temperature of the air.

Valleys, then, are especially warm as compared with the summits on summer days, and especially cold on winter nights. The means given above for Lucerne and Rigikulm illustrate these conditions. The Rigi is 19° colder than Lucerne at 1 p.m. in July, only 5° colder in the morning in January. The Rigi and Bevers present a very striking contrast. The two stations are at almost the same altitude ; but in January the valley station is 14° colder than the summit in the morning, in July 10° warmer during the heat of the day. The range of temperature is therefore least on the Rigi, greatest at Bevers. The lowest reading ever actually recorded in Switzerland, −31°, was taken at Bevers. The Rigi can show nothing below −9°, and even on the Säntis, a summit station 8,200 feet above the sea, the absolute minimum is only −15°. −45° has been recorded on the summit of Mont Blanc. The mean winter temperature is, as a rule, higher well up the sides of a valley than in the bottom. This is one of the reasons that mountain villages are so often built at some distance above the valley floor. The Brünig Pass (3,315 feet above the sea) is somewhat warmer in winter than Meiringen (1,985 feet) which lies below it in the Hasli Thal. ‘ It is especially in November, December, and the first half of January that the higher stations enjoy the greatest climatic advantages, that is to say, when the days are shortest. At that season a gloomy pall of grey fog often enshrouds the lowlands of the Swiss Foreland for a week together, and penetrates into the mountain valleys to an altitude of about 2,500 feet. If we ascend we rise out of the damp, cold, dark, sunless winter climate and come out suddenly into a wonderland of sunshine and beauty. The landscape is full of light, the air is mild but dry and exceedingly bracing, and we enjoy to the full a warm climate only comparable with that of Alpine summits more than 6,500 feet high on clear calm summer days. The sudden change in the meteorological conditions which is experienced above the fog surface is astonishing. In particular the transparency and dryness of the air, together with the bright light, are at first almost overpowering.' (MAURER.)

Temperature inversions are especially notable during anticyclonic conditions, as the following example shows:

Station.	*Altitude. Feet.*	*Temperature at 7 a.m. °F. 1881.* Dec. 25.	Dec. 26.	Dec. 27.
Altdorf	1,480	20	19	23
Rigikulm	5,863	13	27	35
St. Gothard Pass	6,877	−2	24	30

On December 25, 1881, the weather was cyclonic, and the wind strong, and the St. Gothard was 22° colder than Altdorf. But the change to calm anticyclonic conditions on the 26th brought about an extraordinary inversion of temperature. The Rigi was 8° warmer than the valley station, the St. Gothard 5° warmer; the temperature at the St. Gothard had risen 26° in 24 hours; the inversion still continued on the 27th. During anticyclonic calms the coldest air drains slowly downward and collects in the bottoms; but the strong winds associated with cyclones mix the strata, and as the air is driven up the mountain sides and down again into the valleys, the adiabatic temperature changes which occur are hardly masked by other influences; the lowest temperatures are found at the greatest altitudes.

The severest cold is felt in winter in the bottoms of the valleys in the eastern Alps, which are shut off from southern and western influences, and are more frequently subject to anticyclonic conditions. The basins of Klagenfurt and Graz are especially cold, with strong temperature inversion. The following series given by Hann illustrates the conditions at Klagenfurt, in the bottom of its wide, enclosed basin, and at other stations situated at increasing heights on the side of the mountains which enclose the basin on the east:

	Altitude. Feet.	*Mean Temp. January.* °F.		*Altitude. Feet.*	*Mean Temp. January.* °F.
Klagenfurt	1,445	20	Lolling	2,755	27
Eberstein	1,870	24	Do.	3,610	29
Hüttenberg	2,560	26	Stelzing	4,625	25

The higher stations are warmer up to 3,610 feet, above which there is a decrease of temperature with increasing elevation. The figures given are the mean January temperatures. The following is an interesting example of the extreme cases of inversion which may occur during anticyclonic calms. The Obir is a mountain summit which looks down on Klagenfurt from the south-east. The fortnight referred to was one of abnormally high atmospheric pressure over all Central Europe, and the cold was unusually severe.

		December 16–28, 1879.	
	Altitude. Feet.	*Mean Temp. °F.*	*Mean Cloud (tenths of the sky covered).*
Klagenfurt . .	1,445	3	3
Obir . . .	6,695	24	2

We may consider it a general rule that the valley-bottoms are relatively coldest, as compared with the summits, in the coldest winters in Central Europe, relatively warmest in the mildest winters, since cold winters are the result of anticyclonic, mild open winters of cyclonic conditions.

Valleys which have a clear wide opening allow the cold air which gravitates into them to drain away, and they are therefore not so cold as enclosed basins. Such valleys opening towards the north-west of the Alps are indeed abnormally warm in winter. We may compare Altdorf, in the deep Reuss valley just before it opens on to the Lake of Lucerne, and Lucerne at the other end of the same lake, on the Swiss Foreland, at the same altitude.

		Mean Temperature.		
	Altitude. Feet.	*January. °F.*	*July. °F.*	*Range. °F.*
Altdorf . .	1,480	32	64	32
Lucerne . .	1,480	30	65	35

The greater warmth at Altdorf in January is partly due to the better drainage of the cold air, but chiefly to the abnormally warm föhn wind which it enjoys. This is a wind which has crossed the ranges on its journey from the south, and is heated and dried by compression as it descends the northern valleys, and it causes remarkably great and sudden rises of temperature and decreases of humidity at the valley stations. On Christmas morning 1870 Trogen, near St. Gall, recorded a temperature of −1°, and the valley was full of cold foggy stagnant air. But a change set in about noon. A cyclone had appeared to the north of the Alps, and air was drawn in towards it from the south, across the mountains. It blew as a föhn at Trogen, raising the temperature to 41°, a rise of 42° in 24 hours. In the Reuss valley föhn winds blow on an average 48 days per annum, mostly during the winter half-year, and they have a very appreciable effect in raising the mean temperature of the winter months. The föhn effect is lost when the wind passes beyond the narrow valleys (Fig. 86). The valleys of the upper Rhine, the Reuss, and the upper Aar have been well called climatic oases in winter owing to their frequent föhn winds.

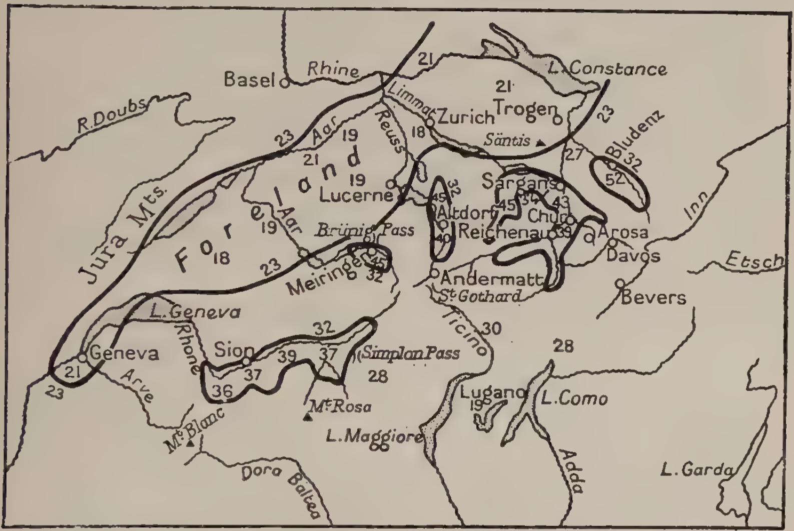

Basel
Rhine
21
L. Constance
21
R. Doubs
Limmat
Zurich
Trogen
23
Bludenz
23
Aar
19
Reuss
18
Säntis
27
32
21
Foreland
19
Lucerne
52
Sargans
45
32
Jura Mts.
Aar
19
45
34
43
Altdorf
Chur
Inn
Brünig Pass
Reichenau
39
Arosa
40
18
23
Meiringen
25
32
Davos
Etsch
Andermatt
St Gothard
Bevers
L. Geneva
32
30
Ticino
28
Geneva
Rhone
Sion
39
37
Simplon Pass
21
Arve
37
28
23
36
Mt Rosa
Lugano
19
L. Como
Mt Blanc
L. Maggiore
Adda
L. Garda
Doro Baltea

FIG. 86. Temperature (°F.) during a Föhn Wind January 13, 1895, 1 p.m., corrected to 500 metres above sea level.

The southern valleys of the Alps are the warmest, owing to their latitude, their southern exposure and sunny skies, and the shelter from the prevailing northerly winds. The means for Lugano and Basel, at the same altitude on opposite sides of the Alps, are:

	Altitude. *Feet.*	*Mean Temperature.* *January.*	*July.*
		°F.	°F.
Basel	910	32	66
Lugano . . .	900	34	71

Cloudiness and Humidity. The valley-bottoms in the Alps are dampest and foggiest (or cloudiest) in winter, especially at night when the air that is chilled by radiation to its saturation point drains down into them from the slopes. The mountain summits on the other hand are clear in winter, but are often hidden in thick cloud during the heat of summer days, when the air movement is upwards in all the valleys, and the masses of vapour condense as the ascending currents cool by expansion. The curves of relative humidity at Lucerne and on the Rigi illustrate these changes (Fig. 87). For the same reasons summer is the sunniest season in the valleys, winter on the summits. On the Säntis the sunniest hour of the day in August is 9 to 10 a.m., just before the heavy mountain clouds form.

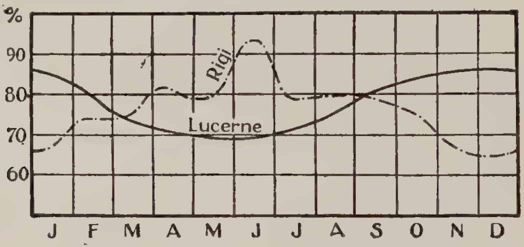


Fig. 87. Mean relative Humidity.

Hence, if we desire a bright sunny climate, we must rise out of the valleys in winter and return to them again in summer.

The driest air is found in different situations under different meteorological conditions. Some of the lowest readings of relative humidity have been taken in the deep northern valleys during strong föhn winds. The air is then often so very dry that villages have been burnt down owing to the wooden chalets easily catching fire. On the other hand, during the temperature inversions of anticyclonic weather the mountain tops are not only warm, but also remarkably dry and sunny, owing probably to the warming and drying by compression of the air which is descending from the upper atmosphere in the anticyclone. At such times the summits offer great climatic attractions to invalids requiring bright invigorating air. But equal advantages in a more accessible form are available in certain elevated valleys, such as those of Arosa and Davos. These resorts are indeed cold in winter, like other valley stations, and the range of temperature from day to night is very great. Davos has the greatest range in Switzerland, and has recorded some of the lowest temperatures, lower than the Säntis, and eclipsed only by Bevers and Andermatt.

	Altitude.	*Mean Temperature. January.*		
	Feet.	*7 a.m.*	*1 p.m.*	*Difference, 1 p.m.–7 a.m.*
		°F.	°F.	°F.
Lucerne	1,480	27	32	5
Davos	5,121	13	27	14
Säntis	8,202	14	16	2

But though Davos is cold it is rarely subject to the chilly wet fogs which so often fill the lower valleys in winter, and the cold is of that dry variety which invigorates. It is especially the clear sunny skies which make the Davos winter climate famous; there is only half as much cloud as at Lucerne, and twice as much sunshine. The snow-clad valley enjoys clear deep-blue skies, crisp calm invigorating air, and powerful sunshine, owing to the absence of moisture and dust particles in the rarefied air, advantages which are prized by many seekers after health. But in summer Davos shares the cloudy skies and moist air of the mountain tops, and has less sunshine than the lower valleys.

The following table shows the relative advantages of the Säntis summit, Davos, Reichenau and Chur, stations in the deep Upper Rhine valley below Davos, and Lucerne and Zürich:

	Altitude.	*Cloud (tenths)*		*Sunshine (hours per day)*		*Relative Humidity. Per cent.*	
	Feet.	*Jan.*	*July.*	*Jan.*	*July.*	*Jan.*	*July.*
Säntis	8,202	5	7	3·9	5·3	75	85
Davos	5,121	4	5	3·2	6·7	84	80
Reichenau	1,982	5	6	—	—	—	—
Chur	2,001	5	5	—	—	90	70
Lucerne	1,480	8	5	—	—	85	72
Zürich	1,542	8	5	1·4	7·7	88	74

We have already referred to the difference in temperature between the north and south sides of the Alps. The south side is favoured in the other climatic factors also:

	Sunshine (hours per day)		*Cloud (tenths)*		*Rainfall.*			
					January.		*July.*	
	Jan.	*July.*	*Jan.*	*July.*	*Amt.*	*No. of days.*	*Amt.*	*No. of days.*
					In.		In.	
Basel	1·9	7·2	7	6	1·5	10	3·5	13
Lugano	4·1	9·4	4	4	2·6	7	6·3	11

Basel and Lugano represent not merely the two sides of a mountain range but two different climates, cloudy Central Europe and the bright Mediterranean.

Rainfall. The rainfall in the Alpine lands is much greater than on the lowlands on both sides, but it is not nearly so great as on lesser mountains situated near the sea. The valleys have much less rain than the ranges which bound them, and the valley lines stand out plainly on the rainfall map. In Switzerland the rainiest districts are the mountain groups which include the St. Gothard and the Säntis; the latter has 96 inches per annum, Sargans in the bottom of the Rhine valley at the foot of the mountain only 50 inches, little more than half as much. The Upper Rhone valley, with less than 24 inches, is the driest part of Switzerland. In the eastern Alps the north and south ranges have the heaviest rainfall, over 60 inches, and the interior valleys least. The smallest totals are in the great longitudinal valley of the rivers Inn, Salzach, and Enns. In the north and centre of the Alps summer is the rainiest season both on the summits and in the valleys, July being the wettest month at most stations. In the eastern Alps the maximum comes somewhat later, in August, and the minimum is in February. In the southern valleys the régime is different; October is the wettest month as in the Mediterranean lands, but the summer half-year is the rainier as in Central Europe.

On the Säntis summit all the precipitation in the months November to April inclusive is in the form of snow, and only in July and August is rain more frequent than snow. At Davos rain is practically never seen from November to March, and there are occasional snowfalls even in June and August; in July alone is all the precipitation rain. In the lower valleys, at Altdorf for example, it never snows from the beginning of May till the end of September; in December, January, and February snow is as frequent as rain. A depth of 20 to 25 feet of snow is not uncommon in the higher valleys such as the Engadine in winter; 45 feet has been measured on the Säntis. Snow covers the ground in an average year for a fortnight at Geneva, a month at Basel, 6 weeks at Altdorf, over 6 months in the Upper Engadine and for 10 months on the Säntis. The lower limit of everlasting snow is estimated at about 9,000 feet above the sea in the western

Alps, 10,500 feet in the drier interior ranges. Deciduous trees and agriculture generally extend up the valley sides to about 4,500 feet; then comes a zone of coniferous forests to about 5,500 feet, separated by grass slopes (alps) and bare rock from the perpetual snows.

CHAPTER XXXI

THE MEDITERRANEAN LANDS

The Mediterranean basin, which has seen the rise of so many of the great civilizations of the world, will always command special attention. Nor are the physical aspects of its geography of less fascinating interest than the human. The Mediterranean climate, in spite of great local differences, possesses an essential unity and individuality among the climates of Europe, and it has produced a very characteristic type of vegetation. The environment was highly favourable for the early development of human culture; and the wide extension of the inland seas, and the climate to which they give rise, has always been one of the great natural advantages of the continent of Europe.

The Mediterranean climate has three main characteristics. (i) Most of the rain falls in the winter half-year, and there is drought, more or less complete, in summer; the periodicity is much greater than in the rest of Europe. (ii) The winters are not only rainy, but very mild; the coldest month has a mean temperature above 40°, and in much of the region above 50°. Summer is very hot as well as dry, the mean July temperature exceeding 70°, and in Africa 86°. Fig. 88 shows that in winter the south-west of the British Isles is as warm as Italy, but the course of the summer isotherm of 70° makes us exclude Britain from the Mediterranean climate province. On the other hand, vast areas in the south-east of Europe are as warm as Italy in summer, but the winters are long, cold, and dry. Perhaps the best indication of the actual extension of the Mediterranean climate is given by the distribution of the olive-tree, one of the most characteristic elements in the Mediterranean vegetation (Fig. 89). (iii) We must add the bright sunny skies—almost cloudless in summer, and far less cloudy even in winter than the skies of North Europe—as an essential element in the climate of the Mediterranean, and probably one of far-reaching influence on human development. The hot sunny weather is ideal for ripening the fruits for which the region is famous.

The general conditions are described on p. 202. They are simplest in summer, when the air movement is controlled by the extension of the North Atlantic anticyclone over Western Europe, from which north-westerly winds blow towards the great low-pressure system covering south Asia and the Sahara. They set in in May and are almost constant in direction during the summer months except for prominent land and sea breezes on the coasts ; they are strong, sometimes of gale force in the eastern Mediterranean. There are many local variations, and we may refer especially to the north winds of the Aegean Sea region, the Etesiae of the ancient Greeks, now called by the Turkish name Meltemi. The winds of the Mediterranean are to a certain extent akin to the trades, and the region may be said to belong to the Sahara in summer. The sky is almost as cloudless, the sunshine almost as abundant, but the expanse of sea prevents the parching heat and drought of the Sahara being realized to the full. Temperature, however, is high, highest in the south and east, lower near the Atlantic. Everywhere as we leave the coasts and go inland we find a rapid increase of heat. The following description of the summer weather in Greece is given by Philippson : ‘ Day after day the sun pours down its fierce rays on the thirsty earth from a deep-blue sky, in which only occasionally is a little white cloud seen. Very rarely there is a passing shower of rain which evaporates at once. The direct rays of the sun are very powerful, and objects exposed to them are heated to an astonishing degree. In the shade the air temperature reaches 105° at times, but the temperature of the sand on the dunes of Phalerum may rise to

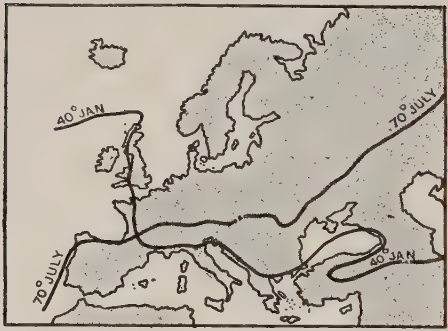


Fig. 88. Mean Temperature.

160°. When it is calm the heated air vibrates over the parched land; at other times the north wind carries thick clouds of dust over the plains in great whirls. Distant islands and promontories appear to float high above the surface of the sea in mirages. Most rivers and streams dry up, and grasses and herbs wither; the harvest is gathered in early in the season. The ground cracks, and lies naked under the heat of the sun. The landscape, which in spring was gay with waving fields of corn or with the green shimmer of sprouting vegetation, now shows the harsh colours of the desert, and the vineyards and maize fields and irrigated gardens alone preserve their bright verdure. In the midday hours all life seems to stop, men and animals drag themselves to shady places to rest, and only the shrill monotonous noise of the cicada fills the air, like the sound of a gigantic rattle. However, the dryness of the air, and the resulting rapid evaporation, make the heat bearable, provided that there is protection from the direct rays of the sun. The heat is intense, but not sultry. Moreover, the air is almost constantly in rapid movement owing to the Etesian winds or the sea-breeze. The heat is far more oppressive in the sheltered valleys and the basins of the interior, or in moist artificially-irrigated agricultural districts, than on the coasts, though even the interior, at any rate at the foot of the higher mountains, is not without a regular air movement. By day the wind blows up the mountains, but hardly has the sun set before one feels the first puffs of the cool wind which descends from the heights, so that in the neighbourhood

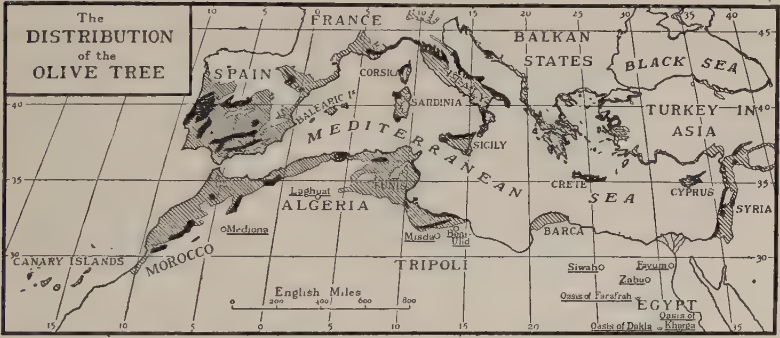

The DISTRIBUTION of the OLIVE TREE
FRANCE
SPAIN
CORSICA
SARDINIA
BALEARIC Is
MEDITERRANEAN
SICILY
ITALY
BALKAN STATES
BLACK SEA
TURKEY IN ASIA
CRETE
SEA
CYPRUS
SYRIA
Laghuat
ALGERIA
TUNIS
Medjona
MOROCCO
CANARY ISLANDS
Misda
Beni-Ulid
TRIPOLI
BARCA
Siwah
Fayum
Zabu
Oasis of Farafrah
EGYPT
Oasis of Kharga
Oasis of Dakla
English Miles
0
200
400
600
800
10
5
0
5
10
15
20
25
30
35
40
45
40
35
30
15
10
5
0
5
10
15
20
35

FIG. 89. The Distribution of the Olive Tree; the black denotes areas of most intensive cultivation.

of mountains some protection against the cold is necessary in the evenings. At night there is everywhere rapid radiation, but nevertheless it is always quite warm, and dew is rare. Nothing is more magnificent than a summer night on the coast of Greece, when the land breeze wafts down cool fragrant air, and the stars sparkle with a fire never seen in our latitudes. The natives sleep in the open air in order to avoid the musty air and the insects of their houses. Summer is also the time of the brightest light, and the most glorious play of colour, especially in the evenings. Every line in the landscape, even at an astonishing distance, is sharply cut, and every tint in the ground shows up brightly since there is little vegetation to hide it.'

But if the climate of the Mediterranean lands is akin to that of the Sahara in summer, in winter there is a close resemblance to north-west European conditions. The pressure distribution is neither so regular nor so constant as in summer. Speaking generally, the Mediterranean is a region of low pressure between the high-pressure belts which cover Central Europe and North Africa. The low pressure is the result of the warmth and humidity over the sea. But the Iberian, Italian, and Balkan peninsulas introduce irregularities, since those lands, narrow as they are, produce tongues of somewhat high pressure, separating the lower pressures over the western Mediterranean, Adriatic, and Aegean Seas; but the difference in pressure is hardly sufficient to show itself on our map of isobars. To speak in terms of the daily weather, we may say that there is a tendency for barometric depressions to form or deepen, and to remain more or less stationary, in the winter months over these seas. The result is that on the west coasts of the peninsulas the winds are frequently from the south, warm and rainy, while the east coasts experience dry and cool north winds. Thus we have here in miniature the climate differences of the east and west coasts of the North Atlantic Ocean. The isotherms for January (Fig. 90) show the temperature conditions clearly, the isotherms running south over the east coast of Italy, and northward again off Dalmatia. Leghorn, on the west coast of Italy, has a mean January temperature of 45°, Ancona in the same latitude on the east coast 42°. Florence in the interior is cooler than either, with 41°. Similarly in Greece, Zante has 53°, Athens 47°, and the interior basins are much cooler than the coasts, as Larissa with 42°, Volo with 45°. Still more striking than the temperature difference is the difference in the rainfall. The mountains that rise steeply from the east coast of the Adriatic are one of the wettest regions of the continent; Crkvice, 3,600 feet above the sea, overlooking the Bocche di Cattaro, has the heaviest rainfall recorded on the mainland of Europe, 183 inches a year, while the opposite shore of the Adriatic has only 20 inches. The east coasts of Greece have about half as much rain as the west coasts, and the eastern parts of Spain are very much drier than the Portuguese coast, where the Serra da Estrella was formerly thought to be the rainiest part of Europe.

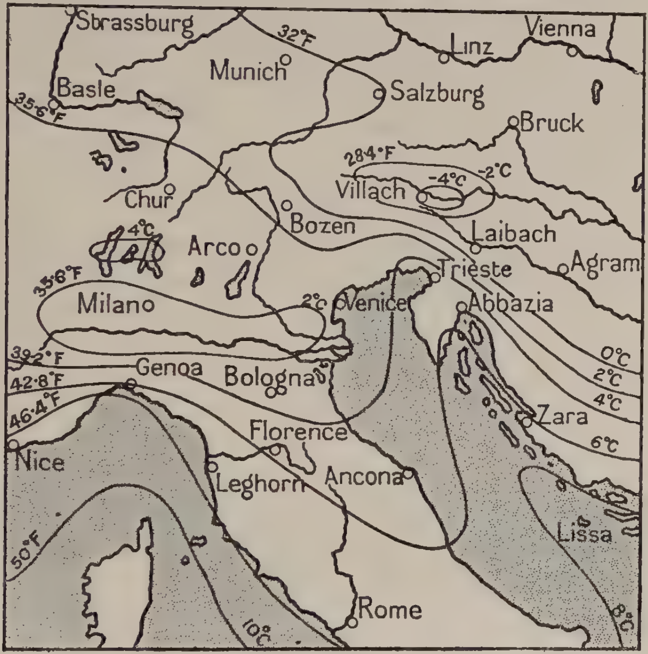

Strassburg
32°F
Vienna
Munich
Linz
Salzburg
Basle
35·6°F
Bruck
28·4°F
-2°C
-4°C
Villach
Chur
Bozen
4°C
Laibach
Arco
Trieste
Agram
35·6°F
Milano
2°C
Venice
Abbazia
0°C
39·2°F
2°C
Genoa
Bologna
42·8°F
4°C
46·4°F
Zara
Florence
6°C
Nice
Leghorn
Ancona
Lissa
50°F
Rome
10°C
8°C

Fig. 90. Mean Temperature in January.

It is the waters of the Mediterranean Sea which produce the winter heat and moisture, and cause the low atmospheric pressure to which the winter conditions are due. Hence we are justified in saying that the Mediterranean climate is the gift of the Mediterranean Sea, and is only found on its shores. If we go far inland in the Iberian or Balkan peninsulas we reach a different climate. The mountain chains which enclose the Mediterranean serve as sharp climatic divides.

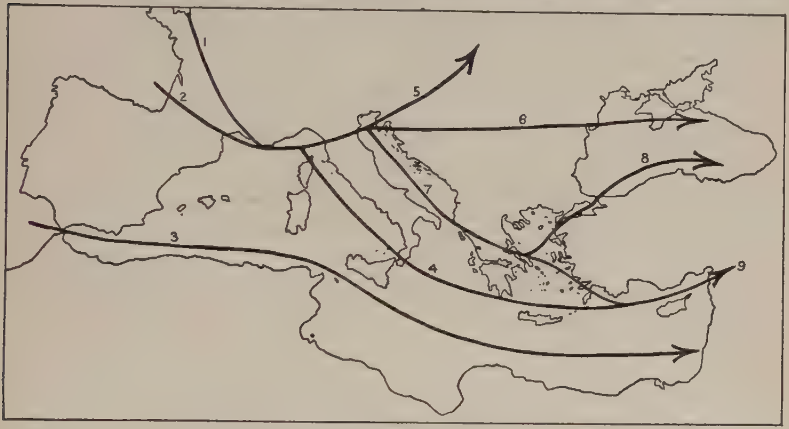
The Mediterranean is a windy region both in summer and winter. 'On the islands of the Greek Archipelago the north winds blow with such force in summer that in many places trees cannot grow on the high ground. In the summer storms the wind remains constant in direction, and does not veer as it does in northern Europe. Such a storm on the Mediterranean is a magnificent sight, and a striking one for those who are accustomed to associate dark skies, driving clouds, and showers of rain with the idea of a storm. Here the sky is deep-blue, and the sea appears indigo, almost black, and the waves roll along with silver crests from which the wind tears shreds of foam. But in winter also there are frequent storms in the Mediterranean, and then the winds are changeable, and the weather is overcast and rainy. Small vessels are much more afraid of the veering winds of the winter storms than of the Etesian winds of summer, which are constant in direction, but often so strong that it is impossible to sail northward against them.' (PHILIPPSON.) The strong winds of summer are due to a temporary steepening of the usual southerly barometric gradient; those of winter are the inflow into the depressions which then follow one another from west to east along the Mediterranean basin.

The prevailing winds are from the north in summer throughout the region; in winter the direction remains much the same in the northern half of the region, since the low pressures are over the axis of the sea, but in south Spain, south Italy, and north Africa the winds are westerly and southerly (Figs. 4 and 5). On the coasts the general currents are obscured, especially in summer, by the land breeze at night and the sea breeze by day, a very regular and important feature.

Local winds, irregular in their time of occurrence, are prominent round the Mediterranean. The Mistral, the 'masterful' north wind, often swoops down in winter in violent gusts over the usually warm littoral between the mouth of the Ebro and Genoa, and is an especially unwelcome visitor in the lower course of the Rhone below Donzère, where the trees bear the mark of its violence in their permanent set towards the south-east, gardens are often surrounded

The cyclone tracks and winds of the Mediterranean.

Many cyclones come from the Atlantic (tracks 1, 2, and 3) often as secondaries, but others spring up over the warm Mediterranean itself, especially over the Gulf of Genoa, the Adriatic, and the Cyprus region, and in these same areas there is a strong tendency for depressions which have come from the Atlantic to deepen. The frequency on each track varies with the seasons. In general cyclones are numerous in the winter half-year, few in summer ; in the eastern basin they are almost unknown from May till September, and summer is a season of unbroken fine weather, deep blue skies, great heat, no rain ; but in the western basin occasional cyclones cause more varied conditions. Track 3 seems to be followed especially in winter, the tracks over the Gulf of Genoa and the Adriatic in autumn, winter, and spring ; in the Gulf of Genoa cyclonic activity is more vigorous in autumn and spring than in winter. Of the tracks that diverge from the Gulf of Venice 5 is followed mostly in spring, 6 especially in spring and summer, the cyclones giving the spring and early summer rains to the steppes of the Lower Danube. The continental block of Asia Minor frequently causes cyclones approaching from the Adriatic to divide into two systems, one following path 8 over the Sea of Marmora into the Black Sea, the other path 9 to the Cyprus region and the coast of Syria. Both these tracks are followed most frequently in winter, but very frequently in spring also ; in autumn cyclones are as numerous on track 8 as in spring, but much less frequent on track 9 ; hence the autumn rains on which agriculture in Syria is largely dependent are liable to be late or deficient (Weickmann).



Cyclone tracks of the Mediterranean region.

The winds in winter are variable as in the belt of the westerlies. But since the cyclones are nearly always situated over the sea the prevailing winds blow from the surrounding lands. Thus round the western basin the winds are SW. on the Algerian coast, SE. to E. on the west side of Italy, N. in France, W. in Spain. Similarly round the Eastern basin there are SW. winds on the coast of Egypt, SE. to E. in Palestine and Syria, N. in Asia Minor. The Black Sea and the Adriatic also have their own cyclonic circulations. Greece and the Aegean have especially variable winds owing to their position between the main low-pressure systems over the western and eastern basins, but the prevailing direction in the Aegean is north.

by a thick fence of cypress for shelter, and the humbler dwellings have openings for doors and windows only on their south-east sides. Such is the force of the Mistral that trains have been overturned by it on the Rhone delta; and a local proverb classes the Mistral with the flooding propensities of the torrential Durance, and the Parlement, as the three scourges of Provence. During a Mistral the sky is often cloudless, but the wind is exceedingly cold and dry, often considerably below freezing-point, and is keenly felt by both the human and plant inhabitants of a coast which usually enjoys less rigorous conditions.

The Mistral is caused by the presence of a depression over the Gulf of Genoa, with an anticyclone over the west of Europe. On the north and west sides of the depression the wind blows in from the Central Plateau of France, the Cevennes, and the Alps, all very cold in winter, and the Rhone valley acts as a funnel for the cold flood. Thus the Mistral is a descending wind. All descending winds are warmed by compression, but the air that feeds the Mistral is so very cold before its descent, that, in spite of the heat acquired by descent, its temperature is still about the freezing-point when it reaches the Mediterranean coast.

A similar wind sometimes blows in winter at the head of the Adriatic Sea, and indeed along the whole Dalmatian coast from Trieste to Albania, and is known as the Bora (*boreas*, the north wind). As in the case of Provence we have here a warm sea in close proximity to a cold land; the temperature difference is very great, the thermal gradient being one of the steepest in Europe (Fig. 90). During the days preceding the Bora, abnormally cold air has been stagnating in the valleys of the Karst plateau and Dinaric Alps, probably during an anticyclonic calm. A depression appears over the Adriatic, and the icy wind sweeps down to the Dalmatian coast in irresistible blasts. The sky is usually clear, and the air very dry, when the Bora blows, as in the case of the Mistral. Cold winds are also a feature of the winter climate on the northern shores of the Aegean Sea; they blow from the cold interior of the Balkan peninsula.

In the middle and south of the Mediterranean basin winds sometimes blow whose qualities are the opposite of those of the characteristic local winds of the north which we have described. They may all be grouped under the name Sirocco (or Scirocco), and they owe their characteristics to their origin in the hot deserts of north Africa and Arabia. As a depression passes along the Mediterranean the winds on its front are sometimes derived from the desert hundreds of miles to the south or south-east, and are abnormally hot and dry, and often carry dust and fine sand. They are most felt in spring when cyclones are numerous, and there is a large difference in temperature between the Mediterranean and the deserts. Generally the Sirocco starts progressively later from the west to the east of the basin as the cyclone which causes it moves eastward, appearing in the Levant four or five days later than in Algeria. After blowing one or two days, or occasionally longer, the Sirocco is replaced by the cooler northerly wind in rear of the depression. Such a prominent feature of the weather has naturally received local names, in south-east Spain levèche, in Algeria sirocco, in Tunis chili, in Tripoli gibli, in Egypt khamsin, in Palestine and Syria sirocco. The high temperature and low humidity continue through the night as well as the day, and in extreme cases much damage may be done to vegetation (ZISTLER).

These desert winds may extend into the middle or even the north of the Mediterranean Sea. As they cross the sea they are somewhat cooled and pick up a great deal of moisture, and on the coasts of Italy and the Aegean (where they are called garbi) they are damp, warm, and depressing, and may give very heavy rain which often contains red dust from the Sahara. The brisk, cool Tramontana, blowing from the north when the depression has passed on, comes as a welcome change. Sometimes while the sirocco is blowing, moist and muggy, in Italy and the Adriatic the cold, dry mistral is sweeping over the Rhone delta, the cyclone which is the cause of both winds lying over the Tyrrhenian Sea. If the sirocco descends from mountains its heat and dryness are intensified by a föhn effect. This is the case on the north coast of Sicily where the highest temperature ever recorded at Palermo, 114°, occurred during a sirocco, and 95° may be exceeded even in the midnight hours. The very high temperatures with south-east winds on the Syrian coast have a similar cause. The frequency of siroccos depends on that of the cyclones which cause them. In the western Mediterranean region they occur on about fifty days each year, distributed over all seasons, but in the Levant they are rather less frequent, and are associated especially with winter and spring;

from June to October they are very rare, since cyclones are almost absent from the east Mediterranean in summer. During the dry Sirocco of north Sicily

> 'the air is misty, the sky yellowish to leaden, filled with heavy vapours, through which the sun can be seen only as a pale disc if at all. Man feels languid and oppressed, and disinclined for mental activity, and animals also suffer from these hot dry winds. Every one stays at home as much as possible and does nothing. When the sirocco is specially hot, its scorching breath does great injury to the vegetation; the leaves of the trees curl up and fall off in a few days. If the sirocco sets in when the olive trees and vines are in blossom, a whole year's harvest may be lost. It is usually heralded by a mist which rises over the southern horizon and overspreads the sky.' (FISCHER.)

Rainfall. The rainfall in the Mediterranean basin varies very much in amount from place to place. The heaviest rainfall of the continent, 183 inches per annum, is recorded on the east coast of the Adriatic Sea; one of the least, 10 inches, in the south of Spain. The rainfall is distinguished from that of the rest of Europe not only by its periodicity, but also by the small number of days on which it falls. St. Malo and Nice have approximately the same mean annual rainfall, but at St. Malo it is distributed over 189 days, at Nice only 67 days. In most of the Mediterranean the number of rainy days is greater than on the Riviera, 80 to 110 days in Italy, but even the highest figures are far less than in the rest of Europe. The dry summers of course contribute largely to this, but even in the rainy winter months there are fewer rainy days than in the north. Thus at S. Remo in October there is a mean rainfall of 6 inches, but it all falls on 7 days; the wettest month at Naples is November, with 4 inches, falling on 13 days. We may compare Portland Bill with 4 inches in October, and 17 rainy days. The rainfall in the winter months is much greater in amount in much of the Mediterranean than in most of North Europe, but it falls more heavily, on fewer days, and in fewer hours on those days. The intensity of the rainfall, especially in the mountains, is a most important point. A result is the liability to very destructive floods in the rivers, whose beds, dry, wide, and gravel-strewn in summer, often become filled in a few hours in winter by swollen torrents. The steep mountain slopes, which improvident man has deforested, are rapidly swept bare of their soil-covering, and the white limestone rock is left to glare in the dazzling sunshine, which soon follows. The week-long palls of cloud, which are so common in North Europe, are almost unknown in the south. The duration of sunshine is 2,316 hours a year at Montpellier, twice as much as in the north of the British Isles, and the record is still greater in the more southern parts of the Mediterranean. Rome has 2,394 hours of sunshine in the year, 11 hours a day in July, the sunniest month, 4 hours a day in December, the least sunny.

From the Azores, throughout the Mediterranean, Black Sea, and Caspian coasts, and as far as Lake Balkash and Afghanistan, most of the rain falls in the winter half-year. But there are considerable differences in the rainfall curve in different parts. In the Mediterranean lands we find the simplest régime in the south, where the early winter is the rainiest period, December or November being the rainiest month; the summer is practically rainless, one or more months being generally quite rainless, with hardly even an occasional thunderstorm. Such are the conditions at Athens (Fig. 91), where in 46 years July was rainless 13 times and August 17 times. Sicily has a similar curve. The dry season becomes shorter towards the north and west. Tripoli has 7 dry months, Malta and Sicily 4, Naples 3, Rome 2, the Gulf of Genoa 1.

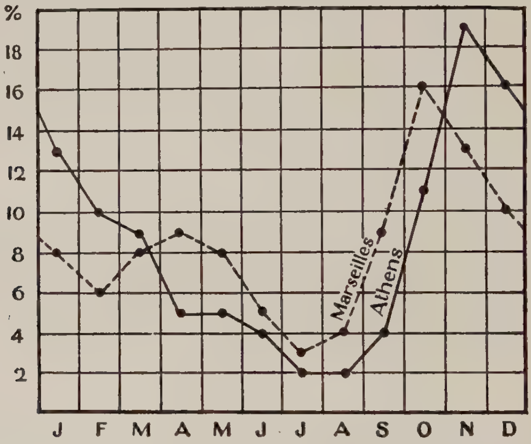


FIG. 91. Monthly Rainfall (percentage of yearly total) at Athens and at Marseilles.

In most of Mediterranean Europe, except the south of Spain, Italy, and Greece, there are two rainfall maxima in the year, the chief in autumn, which is essentially the wet season, and a secondary one in spring; summer is the dry season, but no month can be called rainless, though July comes near being so in many parts (Marseilles, Fig. 91). The line separating these two rainfall types cuts off the south-east of Spain, runs between Sardinia and Corsica, crosses Italy a little north of Sicily, and the Balkan Peninsula from Corfu to Euboea.

The Spanish Meseta has another type of rainfall. There are two maxima, in late spring and autumn, but the spring maximum is the greater, and the summer half-year has more rain than the winter half (Albacete, Fig. 92). This really marks off the Meseta climate from the true Mediterranean type; the rainfall maximum in May is associated with a maximum of thunderstorm activity. A similar régime, but with least rain in winter, is found in the Po plains (Turin, Fig. 92), the Maritsa valley in Bulgaria, and the interior of Georgia (Hellmann).

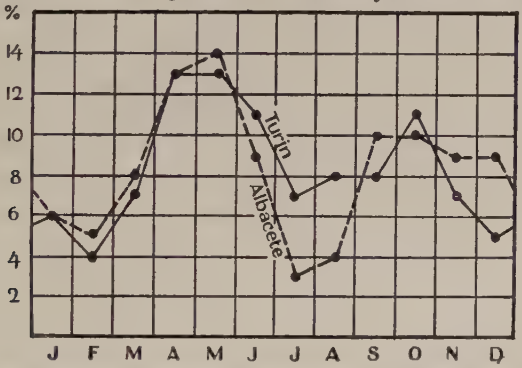


Fig. 92. **Monthly Rainfall (percentage of yearly total) at Albacete and Turin.**

The summer drought necessitates various devices in the plant world for resisting excessive evaporation; thickened stems, thick bark, thorns, waxy coatings, small leaves, growths of hair, are characteristic. Succulents have found a congenial habitat. Summer is the resting time, not winter as in the rest of Europe. 'At the end of April rain showers become rarer and rarer, the sun pours down its fiery rays more and more vertically, the ground becomes dry and hard, and cracks open, or the soil powders to dust. Plants die away, and grey and yellow tints take the place of the glorious blooms, which are now dried up and fallen to dust on the ground. August and September are the months with fewest flowers, the landscape is parched and lifeless, only the cicada is heard among the grey olive trees. The land, which in December gloried in a green carpet of wheat fields, now reminds one of a desolate sun-burnt steppe over which hangs the calina, the peculiar heat haze of the south. So Nature continues to sleep till the rains of autumn rouse her to new life, and the seeds spring up, which were scattered by the short-lived annuals, grasses, and shrubs, before they died. The woody bushes put forth new shoots, and the sap begins to circulate in the tubers and bulbs, which have been protected in the hot ground by their numerous coats.' In the southern Mediterranean lands plant-life continues very active throughout the winter, but on the northern shores the cold at mid-winter is sufficient to check growth, and there is another and greater outburst of energy in spring. For the most luxuriant vegetation heat and moisture must be present at the same time. In the Mediterranean the hot season is rainless and most of the plant growth has to be effected in a comparatively cool season. The natural vegetation is forest, but the trees are of less noble proportions than those of both Central Europe to the north and the tropics to the south, where the growing season is the hottest time of the year. The typical Mediterranean trees are evergreen, so that they are able to continue their slow growth even in summer whenever there may chance to be water; they commonly have very long roots which enable them to obtain water from great depths in the ground. To the absence of rain in the hot season the region owes its healthiness, and considerable immunity from endemic diseases. But where there is much standing water, as in the deltas of the rivers, the coastal marshes, and lake basins, mosquitoes find an excellent breeding-ground, and malaria is so rampant that many such spots have had to be abandoned by man.

Humidity. The air is much drier than in North Europe. Curiously enough, some of the districts with the greatest rainfall have the lowest relative humidity. Genoa, with an annual rainfall of 52 inches, has an average humidity of only 62 per cent., and occasionally readings as low as 8 per cent. are recorded.

Similarly dry air is a feature of all the Italian and French Riviera, and is doubtless due to the descending currents from the mountains to windward. The mean annual humidity at Nice is 66 per cent., at Rome 65 per cent., at Naples 69 per cent.

Temperature. The main features have already been mentioned. The western sides of the peninsulas are warmer than the eastern in winter, and in general the far interior of the Mediterranean region is the warmest part in summer, the coolest in winter (Fig. 93). The following statistics illustrate both these points :

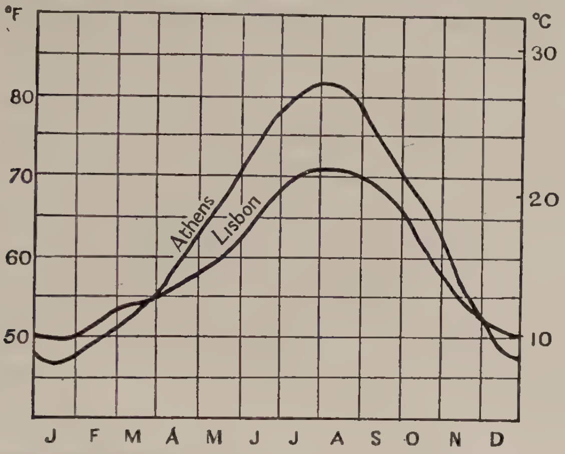


FIG. 93. Mean Temperature at Lisbon (oceanic type) and Athens (interior).

	Mean Temperature.		
	Warmest Month. °F.	*Coolest Month.* °F.	*Range.* °F.
Lisbon (west coast) . . .	70	49	21
Valencia (east coast) . . .	75	49	26
Zante (west coast) . . .	80	53	27
Athens (east coast) . . .	81	47	34

Frost occurs on all the Mediterranean coasts except on the smaller islands in the south, such as Malta. The following table shows that, except on the southern coasts, the thermometer falls well below freezing-point in an average year, especially in the neighbourhood of the Rhone delta, which is subject to the Mistral, the north-east of the Adriatic, and the north of the Aegean, which experience similar cold winds. We find much lower readings immediately we go into the interior of the peninsulas.

	Average lowest Temperature in the Year. °F.	*Absolute lowest on record.* °F.	*Average highest Temperature in the Year.* °F.	*Absolute highest on record.* °F.
Valencia	31	19	99	109
Marseilles	22	11	91	100
Nice	25	15	91	93
Rome	26	16	95	99
Naples	30	24	94	99
Palermo	39	29	98	114
Trieste	23	14	94	99
Salonika	21	14	97	102
Athens	29	20	100	105

Owing to the great heat of the sun's rays, both direct and reflected from the sea, and the strong winds, there are great local differences in climate according to exposure to the one and shelter from the other. The Riviera is specially favoured, and has a mean January temperature only 5° lower than the Algerian coast 480 miles farther south. When we leave the shelter of the mountains round the Gulf of Genoa we must go south along the west coast of Italy as far as Naples before we find again a mean temperature equal to that of Cannes. The Alps provide a similar shelter for the Italian lakes, the Dinaric Alps for the Adriatic coast, and the Yaila Mountains for the south coast of the Crimea; and it has been pointed out that the chief winter resorts of the Mediterranean are situated either in these sheltered positions in the north or else very far south.

Autumn is everywhere very much warmer than spring, a true maritime feature. The moist heat of October is often more oppressive than the hotter but drier weather of July.

Snow is very rare in the south of Italy and Greece, but is not uncommon in the north of Italy, especially in the Po plains and the Apennines, where it is occasionally deep enough to hold up railroad traffic. Very few of the mountains that overlook the Mediterranean Sea are high enough to have a cap of perpetual snow; of the European mountains, the Sierra Nevada alone retain a few patches of snow throughout the summer.

Main climate subdivisions.

The Iberian Peninsula (Fig. 94). This land mass is large enough to develop a modified continental climate. In winter, owing to the cold, there is high atmospheric pressure with outflowing winds, but in the heat of summer pressure is low, and the wind blows inward (Fig. 95). Thus the peninsula modifies the general conditions in its neighbourhood by producing a monsoonal change of wind. A change of wind only, however, not of weather; for the summer season of inblowing winds is a period of almost unbroken drought, since the winds become more and more heated when they blow over the hot land, and therefore have their vapour-capacity increased; being heated, they rise, but are carried away in the outflow in the higher strata of the atmosphere before they are cooled to dew-point by expansion.

1. (Fig. 94.) The Meseta is different in every respect from the coasts. In spite of the altitude the mean summer temperature is higher in New Castile than on the east and west coasts. The days are especially hot on the plateau, but when the sun sets temperature falls rapidly, and the average daily range is 30° in July. The range from summer to winter is also very great, and the winters are far colder than on the coasts. Long spells of frost, and temperatures as low as 15°, are not uncommon. Even at Madrid skating is sometimes possible, and in the mountains and plains of Old Castile traffic is often seriously impeded by snowstorms.

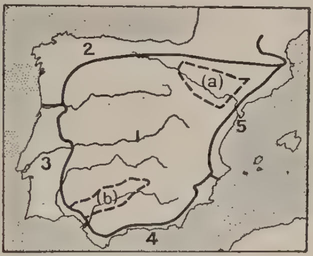


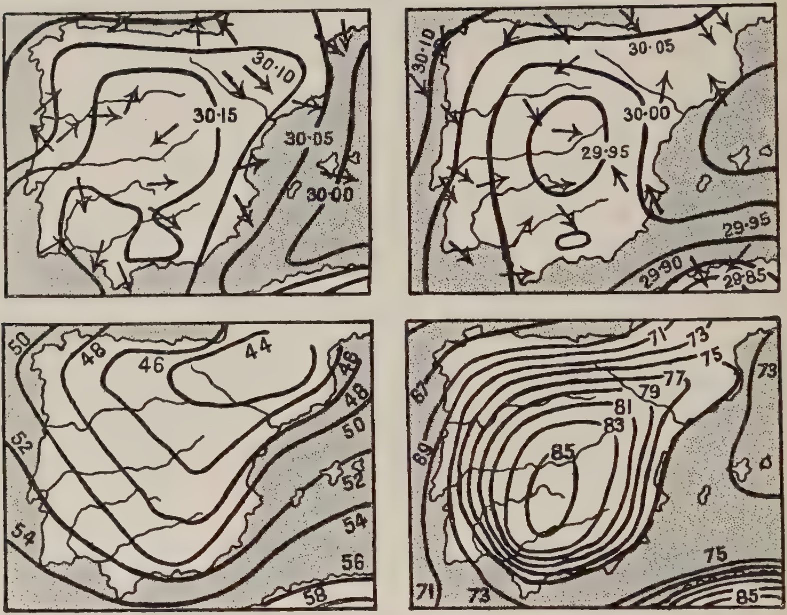
Fig. 94. The major climate regions of the Iberian Peninsula.

Mean Temperature

	Coldest Month.	Warmest Month.	Range.
	°F.	°F.	°F.
Lisbon	49	70	21
Madrid	40	76	36

In summer there is almost complete drought, broken only by an occasional thunderstorm, and the fierce heat burns up the vegetation. The landscape is semi-desert, yellow and grey are the dominant colours, and dust is everywhere—the parched ground is covered with dust, and the air is hazy owing to the presence of minute dust particles which have been swept up by the strong winds. The haze is known as the 'calina,' and is probably due to irregular refraction of the light as well as to dust. The view is frequently obscured by the dismal grey calina in all the south Mediterranean lands.

The Ebro plains (*a*) lie lower, but have about the same temperature as Madrid owing to their more northern position. The rainfall is small and much of the land is steppe. The plain of Andalusia (*b*) in the south is the hottest part of the peninsula and probably of all Europe, and in summer the heat is excessive. At Seville in an average year the thermometer rises as high as 118°, a figure which approaches the highest records from the Sahara. The rainfall is scanty, as in most of the rest of the interior of Spain except the mountains.


30·10
30·15
30·05
30·00
30·10
30·05
30·00
29·95
29·95
29·90
29·85
50
48
46
44
46
48
50
52
52
54
54
56
58
71
73
75
77
79
81
83
85
67
69
73
75
71
73
85

January *July*

Fig. 95. Pressure, Winds, and Temperature over the Iberian Peninsula. T. de Bort.

The high pressures of winter check the ingress of the rain storms of that season, so that February is not much rainier than July. Spring is the rainiest season, and this fact, together with the strong winds and extreme temperatures, favours steppe vegetation.

2. (Fig. 94.) The north coast has a west-European coastal climate, with equable temperature, and heavy rainfall. The

rainfall is considerable even in summer, owing to the monsoonal indraught, but much greater in winter.

3. (Fig. 94.) The west coast has the most oceanic variety of Mediterranean climate—cool summers, mild winters, small temperature range, moist air, and abundant rain in the winter half-year. The summer months are almost rainless.

4. (Fig. 94.) The south and south-east coasts are sheltered by the Sierra Nevada, and are especially distinguished by their hot sunny summers. The climate resembles that of Andalusia, but the sea reduces the range of temperature. The rainfall is small (maximum in September), but there is good irrigation from the streams fed by the melting snow on the mountains. The most tropical fruits of the continent are grown here, the date palm ripens its fruit, bananas are cultivated, and also the sugar-cane.

5 (Fig. 94) resembles 4, but is cooler in all seasons.

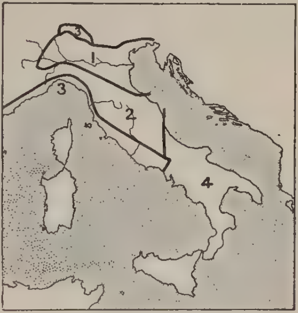


FIG. 96. Major climate regions of Italy.

Italy. 1. (Fig. 96.) The Po plains are akin to Central Europe rather than the Mediterranean in climate. The summers are almost as hot as in Sicily, but the winters are cold, very much colder than on the Riviera at the other side of the Apennines (Fig. 90); for the plains are frequently covered with cold damp air which has drained down on to them from the mountain valleys. There is a well-marked ‘ temperature inversion ’; the cold air lies on the lowest ground, and if we rise we enter warmer strata. The Italian lakes have a much milder winter, and lemon groves and olive trees flourish, signs of a Mediterranean climate. When we cross the Alps from the north, we seem to enter a new world in this mild and sunny region, but on continuing to descend we return to the Central European winter at Milan, where snow often lies for days, and skating is sometimes enjoyed. Piacenza has the same mean January temperature as Berlin, a far lower one than Skomvaer in the south of the Lofoten Islands. Even the rapid River Po and the lagoons round Venice have been frozen over, but not within living memory; Venice is somewhat milder than the plains to the west, owing to the influence of the sea.

The rainfall is more evenly distributed over the year than in the rest of the Mediterranean lands, and, in opposition to the régime elsewhere, the summer half-year has more rain than the winter half. The rainiest months are in spring and autumn, the driest are January and February. The summer rain, and the abundant water for irrigation provided by the mountain torrents, enable large crops of maize and rice to be produced here only in Italy.

2. (Fig. 96.) The northern Apennines and the highlands of Tuscany carry the Central European climate far south. There is most rain in the winter half-year, but summer is not rainless. Frost usually occurs even on the coasts of northern Italy every winter, and the mountains are sometimes buried deep in snow.

3. (Fig. 96.) The Riviera has been described already.

4. (Fig. 96.) South Italy has an exceedingly dry and hot summer, even in the mountains. Frost is rare. The climate is typically Mediterranean. There is a single maximum in the rainfall curve about November.

The Balkan Peninsula. 1. (Fig. 97.) The west coast has a true Mediterranean climate, with very wet but mild winters, subject, however, to the Bora.

2 (Fig. 97) has very hot, dry, and sunny summers, described on page 234, and comparatively cold winters, but frost is almost unknown on the coasts, especially on the islands. There is a well-marked rainfall maximum in November, December, and January.

3. (Fig. 97.) The north coast of the Aegean also has a Mediterranean climate, and the olive is a common tree. But the colder winters make us classify it as a separate region. An anticyclone often lies in winter over the Balkans to the north and a cold northerly wind comes down the valleys to the coast. Under such conditions a reading of 14° F. was once observed at Salonika, and much of the inner gulf had a thin coating of ice. On most January nights the mercury falls nearly to freezing-point.

4 (Fig. 97) has a transition climate between the Mediterranean and the steppes. Most of the rain falls in winter, as in the Mediterranean lands, but there are often bleak north

winds from the steppes of south Russia, bringing low temperatures and precluding the typical Mediterranean flora. The olive does not flourish. The northern plains are coldest; Constantinople is somewhat warmer owing to its peninsular situation, but the Bosphorus has been covered with ice, so that the passage from Europe to Asia could be made on foot. The ice, however, had probably drifted from the coasts of the Black Sea and, being compacted in the narrow channel by the current, had frozen into a solid covering.

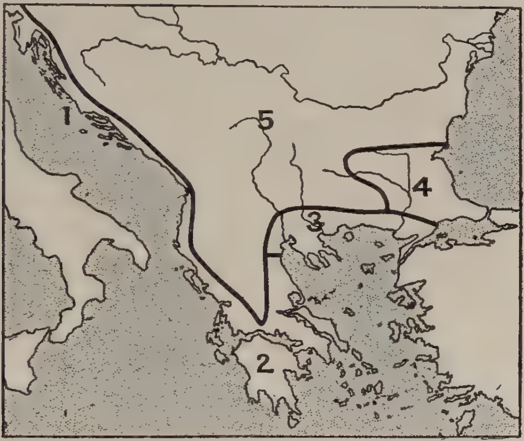


FIG. 97. Major climate regions of the Balkan Peninsula.

5 (Fig. 97) must be classed with Central Europe, having rain all the year, with maxima in May and June and October as in south Hungary. The winters are cold for the latitude. Much of this division is mountainous. The Mediterranean vegetation of the coasts of the Aegean is replaced by the forest trees characteristic of Central Europe.

STATISTICS

MEAN TEMPERATURE (°F.)

NORTH-WEST EUROPE

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
British Isles.															
Valencia	30	44·4	*44·3*	45·0	48·0	52·2	56·7	58·8	**58·9**	56·6	51·5	47·5	45·5	50·8	14·6
Birr	175	*39·8*	40·6	41·9	46·1	51·3	56·7	**58·8**	58·1	54·6	47·9	43·1	40·6	48·3	19·0
Dublin	12	*42·1*	42·5	43·6	47·0	51·8	57·1	**60·1**	60·0	56·0	50·2	45·8	42·7	49·9	18·0
Scilly	131	45·7	*45·3*	46·0	48·6	52·5	57·2	60·5	**60·8**	58·6	53·8	49·8	47·4	52·2	15·5
Dungeness	21	*39·3*	39·9	41·7	46·1	52·0	57·3	60·9	**61·4**	58·2	51·7	45·7	41·7	49·7	22·1
London (Kew)	18	*38·9*	40·1	42·4	47·3	53·4	59·2	**62·7**	61·6	57·1	49·9	44·0	40·3	49·7	23·8
Oxford	208	*38·4*	39·7	42·1	47·0	52·8	58·5	**61·9**	60·9	56·6	49·4	43·5	39·9	49·2	23·5
Cambridge	41	*37·6*	39·1	41·8	46·7	52·8	58·5	**61·9**	61·1	56·9	49·4	43·1	38·9	49·0	24·3
Holyhead	15	41·8	*41·7*	42·7	46·4	50·8	55·8	58·5	**58·7**	56·4	51·0	46·6	43·4	49·5	17·0
Buxton	987	*35·3*	36·1	38·2	42·9	48·5	54·4	**57·4**	56·4	52·3	45·7	40·4	36·6	45·4	22·1
York	56	*37·9*	39·1	41·5	46·0	51·7	57·6	**60·5**	59·7	55·6	48·6	43·0	39·0	48·3	22·6
Leith	18	*39·1*	39·5	41·3	45·4	50·1	55·7	**58·6**	58·3	54·7	48·5	43·3	39·9	47·9	19·5
Fort William (1884–1903)	171	39·2	*38·8*	40·4	44·9	49·9	55·4	**56·9**	56·3	53·2	46·9	43·7	39·9	47·1	18·1
Ben Nevis (1884–1903)	4,406	24·1	*23·8*	24·0	27·6	33·0	39·7	**41·1**	40·4	38·0	31·4	28·9	25·2	31·4	17·3
Nairn	82	*37·2*	37·6	39·5	43·9	48·8	54·2	**56·7**	56·2	52·7	46·1	41·2	37·6	46·0	19·5
Braemar	1,120	*34·3*	34·4	36·0	40·7	46·2	52·6	**54·8**	53·6	49·9	43·5	38·4	34·8	43·3	20·5
Orkney (Deerness)	160	39·0	*38·5*	39·2	42·3	46·3	50·7	**53·5**	53·4	51·4	46·9	42·8	40·0	45·3	15·0
France.															
Biarritz	115	*45·9*	47·7	50·0	54·3	58·8	64·2	68·4	**68·9**	64·8	59·2	50·9	46·8	56·7	23·0
Pic du Midi	9,383	*17·8*	18·3	19·2	22·6	28·9	37·0	43·5	**43·5**	37·8	30·6	23·7	19·6	28·6	25·7
Bordeaux	246	*40·6*	43·2	46·9	53·1	58·3	64·2	**68·2**	68·2	63·7	55·4	46·9	41·2	54·1	27·6
Nantes	131	*40·1*	41·9	45·1	51·3	56·3	62·2	**65·7**	64·9	60·4	52·9	45·3	40·6	52·2	25·6
Paris	164	*36·5*	39·0	43·2	50·5	56·1	62·4	**65·5**	64·4	59·0	50·5	42·8	37·2	50·5	29·0
Lille	66	*36·0*	38·1	41·7	48·4	54·3	60·4	**63·5**	63·1	58·8	50·5	42·3	36·9	49·5	27·5

NORTH-WEST EUROPE (*continued*)

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Holland and Belgium.															
Brussels . . .	328	*34·4*	36·1	39·7	46·9	53·2	59·7	**63·0**	62·2	57·7	49·5	41·2	35·6	48·2	28·6
Utrecht . . .	43	*34·2*	35·6	39·2	46·4	53·2	59·9	**62·6**	62·1	57·2	48·9	40·5	35·8	48·0	28·4
Groningen . . .	33	*33·4*	35·2	38·3	45·0	52·0	58·6	**61·7**	61·2	56·7	48·6	39·7	35·4	47·1	28·3
Germany.															
Hamburg . . .	82	*32·5*	33·4	37·4	45·0	52·9	60·1	**63·0**	61·9	56·5	48·2	38·5	33·6	46·9	31·5
Norway.															
Skudesnaes . .	16	35·8	*34·5*	35·8	41·5	47·7	53·8	57·0	**57·9**	54·3	47·3	40·8	37·0	45·3	23·4
Bergen . . .	66	34·2	*33·6*	35·4	42·1	48·9	55·0	**57·9**	57·6	52·7	45·1	38·5	34·7	44·6	24·3
Lärdal . . .	16	29·7	*29·5*	32·7	42·3	50·9	57·7	**60·6**	59·2	51·5	42·6	34·9	29·8	43·5	31·1
Ona	33	36·9	*35·6*	36·1	39·9	44·6	49·5	53·8	**54·7**	52·0	46·2	40·5	37·6	43·9	19·1
Christiansund . .	49	34·9	*33·6*	34·9	39·9	46·0	52·2	55·6	**55·8**	51·5	44·6	38·1	35·4	43·5	22·2
Trondhjem . .	33	27·3	*26·8*	30·0	37·9	45·9	53·4	**57·2**	56·3	50·0	41·2	32·7	27·5	40·5	30·4
Röros . . .	2,067	12·9	*12·4*	18·3	28·6	39·2	48·9	**52·2**	50·7	43·3	32·4	21·0	13·6	31·1	39·8
Skomvaer . . .	66	33·8	*31·5*	32·0	36·0	41·4	46·6	49·8	**51·1**	47·5	42·4	38·7	36·0	40·6	19·6
Tromsö . . .	49	26·6	*25·0*	26·6	31·5	38·8	47·3	**51·8**	51·1	44·8	36·0	30·0	27·1	36·3	26·8
Fruholmen . .	49	26·4	*25·9*	26·2	30·4	37·0	43·7	48·9	**49·8**	44·1	36·5	30·7	27·5	35·6	23·9
Vardö . . .	200	21·7	*21·2*	23·0	28·9	34·7	42·4	47·5	**48·6**	43·2	34·7	27·9	23·9	33·1	37·4
Denmark.															
Fanö . . .	16	*31·8*	31·8	34·7	41·7	50·2	57·4	**59·9**	59·0	54·0	46·0	38·8	33·6	45·0	28·1

MEAN TEMPERATURE (°F.), *continued*

CENTRAL EUROPE

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
France.															
Clermont-Ferrand	1,280	*35·4*	38·5	42·8	50·4	55·8	62·2	**66·0**	64·8	58·6	50·5	42·4	36·1	50·4	30·6
Puy de Dôme	4,823	*28·1*	28·8	29·7	35·1	40·8	47·8	**52·0**	51·8	47·8	40·1	34·0	28·8	38·7	23·9
Lyon	574	*35·1*	38·5	43·9	51·6	57·9	64·4	**68·2**	66·7	60·9	51·8	42·4	35·2	51·4	33·1
Germany.															
Karlsruhe	410	*32·9*	35·8	41·2	49·5	56·5	63·3	**66·2**	64·8	58·6	49·5	40·5	34·0	49·5	33·3
Munich	1,739	*27·3*	30·4	36·1	45·3	53·1	59·7	**63·0**	61·5	55·4	46·0	35·6	28·6	45·1	35·7
Hanover	180	*32·7*	33·8	37·6	45·7	53·8	60·3	**63·1**	61·5	56·3	47·7	38·5	33·8	47·1	30·4
Erfurt	656	*30·7*	32·7	37·2	45·9	54·1	61·0	**63·9**	62·4	56·5	47·7	37·8	32·0	46·8	33·2
Brocken	3,756	24·8	*24·3*	26·2	33·8	41·5	48·4	**51·4**	50·5	46·0	38·7	29·8	25·2	36·7	27·1
Kiel	16	*33·6*	33·8	36·7	44·4	51·8	59·5	**62·6**	61·7	56·5	48·7	39·7	35·2	46·9	29·0
Berlin	164	*31·3*	32·5	37·0	45·9	54·9	62·1	**64·6**	63·3	57·0	48·2	38·1	32·7	47·3	34·3
Leipzig	394	*30·6*	32·2	36·9	45·7	54·5	61·9	**64·8**	63·0	56·7	47·5	37·4	31·8	46·9	34·2
Stettin	98	*30·7*	31·6	36·0	45·3	54·0	61·9	**65·1**	63·5	57·4	47·8	37·8	32·2	46·9	34·4
Posen	213	*29·3*	30·0	35·2	45·5	54·9	62·8	**65·5**	63·7	56·8	47·5	36·9	30·4	46·6	36·2
Königsberg	16	*26·8*	27·1	31·6	41·9	51·3	59·7	**63·1**	61·9	55·6	45·7	35·2	28·6	44·1	36·3
Scandinavia.															
Copenhagen	16	32·2	*31·8*	34·5	41·7	50·7	58·6	**61·9**	60·6	55·4	47·3	40·1	34·5	45·9	30·1
Göteborg	33	30·7	*30·4*	33·1	41·7	50·7	59·0	**62·2**	60·6	54·9	46·0	38·5	32·7	45·0	31·8
Christiania	82	24·1	*23·9*	29·5	39·9	50·9	59·9	**62·6**	60·6	52·7	41·9	32·2	25·5	41·9	38·7
Carlstad	180	25·8	*25·5*	29·7	38·7	49·1	59·2	**62·4**	59·9	52·7	43·0	34·2	27·3	42·3	36·9
Stockholm	148	26·6	*25·7*	28·9	37·8	47·3	57·4	**62·1**	59·5	52·7	43·0	34·9	28·4	42·1	36·4
Röros	2,067	12·9	*12·4*	18·3	28·6	39·2	48·9	**52·2**	50·7	43·3	32·4	21·0	13·6	31·1	39·8
Hernosand	344	20·5	*19·9*	25·3	34·2	43·0	54·5	**59·2**	56·8	49·6	39·4	30·4	22·1	37·9	39·3
Haparanda	33	11·7	*10·6*	16·9	28·6	39·4	52·9	**59·0**	55·0	46·0	34·5	23·0	14·0	32·5	48·4

CENTRAL EUROPE (*continued*)

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Switzerland.															
Basel	909	*31·8*	36·0	40·8	49·3	56·1	62·8	**66·4**	64·6	58·6	48·6	40·6	33·1	49·1	34·6
Geneva	1,329	*32·0*	35·6	40·8	48·9	55·9	62·8	**67·1**	64·9	59·2	49·1	40·8	33·6	49·1	35·1
Lucerne	1,480	*29·7*	33·3	38·7	47·5	54·9	61·5	**64·9**	62·8	57·4	47·1	38·7	31·3	47·3	35·2
Altdorf	1,480	*32·4*	35·6	40·6	48·7	55·4	61·2	**64·4**	63·1	58·3	49·1	40·8	33·4	48·6	32·0
Andermatt	4,741	*19·9*	23·5	28·0	35·6	43·0	49·5	**53·2**	51·8	47·3	38·5	29·8	21·7	36·9	33·3
St. Gothard	6,877	*18·1*	19·2	20·8	27·7	34·3	40·8	**46·2**	45·7	41·4	32·4	24·6	19·2	30·9	28·1
Sargans	1,663	*29·8*	34·4	39·9	48·4	55·2	60·8	**63·9**	62·4	58·1	48·6	39·6	31·1	47·7	34·1
Säntis	8,202	*16·2*	16·3	16·9	23·5	30·6	36·5	**41·0**	40·5	37·2	28·9	22·8	17·4	27·3	24·8
Davos	5,121	*18·7*	22·8	27·3	36·1	44·1	50·4	**53·8**	52·2	47·1	37·9	29·7	21·0	36·9	35·1
Bevers	5,610	*14·2*	18·7	24·4	33·3	42·4	49·3	**53·2**	51·3	45·9	36·3	26·1	16·0	34·4	39·0
Austria, Hungary, etc.															
Innsbruck	1,968	*26·1*	30·9	38·7	47·8	55·2	61·2	**64·0**	62·4	57·0	47·8	36·9	27·3	46·2	37·9
Klagenfurt	1,444	*20·5*	25·9	35·2	47·1	55·8	62·8	**65·8**	63·9	56·8	46·9	34·5	23·7	45·0	45·3
Graz	1,214	*25·9*	30·9	37·9	47·8	56·1	62·2	**65·3**	63·5	57·2	47·8	36·5	27·9	46·6	39·4
Vienna	656	*28·9*	32·4	39·0	48·9	57·2	63·9	**67·3**	65·8	59·4	49·6	38·3	30·9	48·6	38·4
Lemberg	1,115	*24·3*	25·7	33·1	46·0	57·0	63·3	**66·4**	64·9	57·0	47·3	34·7	26·2	45·5	42·1
Budapest	509	*28·2*	31·6	39·9	51·1	60·1	66·7	**70·3**	68·5	61·0	51·1	39·0	30·6	49·8	42·1
Agram	509	*30·9*	35·1	43·0	52·7	60·6	67·1	**70·9**	69·4	62·4	53·4	41·9	33·1	51·6	40·0
Debreczin	459	*25·2*	30·2	38·5	51·1	60·1	67·5	**70·9**	69·1	61·5	50·9	38·1	28·9	49·3	45·7
Balkan States.															
Belgrade	459	*29·1*	33·8	43·0	52·0	61·5	67·1	**71·6**	70·5	63·3	55·2	42·6	34·2	52·0	42·5
Sofia	1,804	*26·6*	29·5	39·2	50·0	58·6	65·1	**69·3**	67·5	60·6	51·8	40·1	30·9	49·1	42·7
Uskub	804	*29·5*	34·2	45·1	53·2	62·1	68·7	**73·8**	72·1	66·4	57·0	43·0	34·0	53·2	44·3
Bukarest	279	*25·5*	29·3	39·7	51·8	61·3	68·2	**73·0**	71·4	63·7	53·6	40·5	30·2	50·7	47·5
Sulina	7	*28·9*	32·0	39·4	49·1	60·4	68·2	**72·5**	71·4	64·2	55·8	43·7	35·1	51·8	43·6

MEAN TEMPERATURE (°F.), *continued*

THE MEDITERRANEAN LANDS

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Spain and Portugal.															
Santiago	886	*45·1*	47·1	48·9	51·8	56·7	62·2	64·8	**66·0**	62·4	55·6	50·7	46·4	54·9	20·9
Lisbon	66	*49·3*	52·0	54·1	56·5	60·8	66·4	70·2	**70·2**	68·0	61·5	56·1	50·7	59·5	20·9
Gibraltar	49	*54·0*	55·0	56·3	60·6	64·6	70·2	73·9	**74·3**	71·1	64·8	59·0	54·7	63·1	20·3
Murcia	197	*50·2*	53·2	56·3	60·8	66·2	73·0	78·8	**78·8**	73·4	66·0	58·3	51·6	63·9	28·6
Barcelona	131	*46·4*	49·5	51·3	55·8	61·7	68·5	**73·9**	73·4	68·9	61·0	54·0	47·8	59·4	27·5
Burgos	2,920	*34·5*	38·8	41·7	46·8	52·2	59·4	**64·4**	64·2	58·5	48·9	42·1	35·6	48·9	29·9
Madrid	2,149	*39·7*	43·9	47·5	52·3	59·4	68·5	**75·7**	74·8	66·4	54·9	47·1	40·1	55·9	36·0
Ciudad Real	2,083	*41·4*	45·7	49·3	54·3	61·2	70·3	**77·5**	76·6	67·8	56·7	48·9	41·7	57·6	36·1
Seville	66	*52·2*	55·9	59·5	63·9	69·6	78·1	84·7	**84·9**	78·1	68·4	60·1	52·9	67·3	32·7
France.															
Montpellier	115	*41·0*	43·9	48·0	54·5	61·2	67·6	**72·9**	71·6	65·5	57·0	48·2	42·1	56·1	31·9
Marseilles	246	*43·3*	45·3	48·6	54·7	61·0	67·6	**72·1**	71·1	66·0	58·1	49·8	44·1	56·8	28·8
Nice	66	*46·4*	47·5	50·7	56·5	62·2	69·1	**73·8**	73·2	68·2	61·0	52·7	47·3	59·4	27·4
Italy.															
Genoa	177	*45·5*	47·7	51·5	57·6	63·3	70·0	**75·4**	75·2	70·7	62·1	53·2	47·3	59·9	29·9
Alessandria	322	*31·1*	36·5	45·1	54·5	61·9	69·6	**74·5**	73·2	66·0	55·0	43·0	34·7	53·8	43·4
Milan	482	*32·4*	38·1	46·0	55·2	62·6	70·0	**74·8**	73·0	66·0	55·6	44·1	35·6	54·5	42·4
Lugano	902	*34·4*	38·3	44·4	52·5	59·2	66·4	**70·7**	68·9	63·0	52·7	43·2	36·1	52·5	36·3
Florence	240	*40·8*	43·9	48·9	56·1	63·1	70·7	**76·1**	74·8	68·5	58·8	49·3	42·6	57·7	35·3
Rome	164	*44·1*	46·6	50·7	56·8	64·0	71·2	**76·6**	75·7	70·2	61·7	52·3	45·9	59·7	32·5
Naples	492	*46·8*	48·4	51·5	56·8	63·7	70·3	**75·6**	75·0	69·8	63·1	54·7	48·7	60·4	28·8
Palermo	230	*50·5*	52·2	54·7	58·6	64·0	70·7	76·3	**76·6**	73·4	67·3	59·4	53·4	63·1	26·1
Balkan States.															
Trieste	220	*39·4*	40·8	45·9	54·3	61·5	69·3	**73·4**	72·3	66·4	58·1	48·4	41·7	55·9	34·0
Ragusa	49	*47·7*	48·9	51·6	57·4	64·6	72·0	**77·0**	76·6	72·1	65·1	56·1	50·4	61·7	29·3
Corfu	98	*50·4*	51·1	53·2	59·7	66·4	73·6	78·4	**78·6**	74·3	67·8	59·4	53·4	63·9	28·2
Athens	351	*46·4*	47·5	52·3	58·8	67·8	75·7	**80·6**	79·9	73·9	66·0	57·0	50·0	63·0	34·2
Salonika	7	*40·6*	44·2	49·8	57·6	67·5	73·6	**78·6**	77·4	70·9	63·0	51·4	44·6	59·9	38·0
Constantinople	246	*40·6*	41·0	45·5	52·3	61·0	69·1	**73·2**	72·5	67·3	61·3	52·5	45·3	56·8	32·2

MEAN RAINFALL (inches)

NORTH-WEST EUROPE

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
British Isles.														
Valencia	30	5·5	5·2	4·5	3·7	*3·2*	3·2	3·8	4·8	4·1	5·6	5·5	**6·6**	55·6
Dublin	47	2·3	1·9	*1·9*	1·9	2·0	2·0	2·6	**3·0**	*1·9*	2·7	2·7	2·5	27·4
Plymouth	116	3·3	2·9	2·9	2·2	*2·1*	2·1	2·8	**3·0**	*2·4*	3·9	3·6	**5·0**	36·2
London (Camden Square)	110	1·9	1·7	1·8	*1·5*	1·8	2·0	**2·4**	2·2	*1·8*	**2·6**	2·4	2·4	24·5
Oxford	208	1·8	1·6	*1·6*	1·6	1·9	2·2	**2·4**	2·3	*1·7*	**2·9**	2·3	2·5	24·8
Shrewsbury	191	1·9	*1·5*	1·7	1·5	2·0	2·1	2·3	**3·0**	*1·7*	**2·9**	2·2	2·3	25·2
Buxton	987	4·5	3·7	4·1	*2·9*	3·1	3·2	3·9	**4·4**	*3·2*	4·9	4·7	**5·7**	48·4
Nottingham	82	1·7	1·5	1·6	*1·3*	1·8	1·9	2·3	**2·4**	*1·6*	**2·4**	1·8	2·3	22·5
Seathwaite	422	13·3	11·9	11·2	7·4	7·4	*6·5*	8·5	**11·6**	*9·9*	12·0	13·6	**16·3**	129·5
Newcastle	201	2·0	1·6	2·1	*1·6*	2·0	2·2	2·6	**2·9**	*2·0*	**3·2**	2·4	2·4	27·2
Glasgow	180	3·3	2·9	2·7	*2·1*	2·6	2·5	3·1	**3·9**	*3·0*	3·4	3·6	**4·2**	37·2
Edinburgh	227	1·7	1·6	1·9	*1·4*	2·0	1·9	2·7	**3·1**	*2·0*	**2·6**	2·1	2·2	25·0
Fort William (1891–1903)	171	8·7	6·9	7·2	4·2	*3·5*	3·5	4·6	6·9	**8·2**	7·9	*7·5*	**11·3**	80·4
Ben Nevis (1891–1903)	4,406	18·7	15·1	17·0	10·2	8·3	*7·8*	11·3	14·0	**16·9**	*14·8*	16·0	**21·2**	171·3
Nairn	82	2·0	1·8	1·9	*1·5*	1·8	1·8	**2·7**	2·4	2·2	2·4	2·4	2·2	24·9
France.														
Bayonne	66	3·9	3·3	3·9	3·7	3·3	3·6	*2·5*	2·9	4·3	**5·5**	5·4	4·1	46·4
Bordeaux	33	2·5	*2·0*	2·3	2·5	**2·8**	2·8	*1·9*	2·0	2·6	**3·6**	3·1	2·7	30·7
Brest	217	3·3	2·6	2·0	2·1	*1·8*	2·0	2·0	2·2	2·8	**3·9**	3·6	3·4	31·6
Cherbourg	59	3·3	2·4	2·3	*1·8*	2·0	1·9	2·0	2·4	3·2	**4·8**	4·1	3·7	34·0
Paris (St. Maur)	164	1·5	*1·2*	1·6	1·7	2·1	**2·3**	2·2	2·2	*2·0*	**2·3**	1·8	1·7	22·6
Lille	85	2·0	*1·6*	1·9	1·6	2·2	2·2	**2·7**	*2·4*	2·5	**3·1**	2·4	2·4	27·0
Holland and Belgium.														
Ostend	13	2·0	1·6	1·9	*1·5*	1·9	1·9	2·2	**2·9**	2·8	*2·6*	**3·1**	2·3	26·8
Brussels	187	2·2	*1·9*	2·0	1·9	**2·3**	2·5	2·9	**3·0**	2·6	2·8	2·5	2·4	28·9
Utrecht	121	2·1	1·7	2·0	*1·7*	2·0	2·3	3·1	**3·4**	2·7	3·0	2·4	2·6	29·1
Helder	13	2·0	1·6	1·7	*1·3*	1·5	1·7	2·2	3·1	2·9	**3·5**	2·7	2·4	26·8

MEAN RAINFALL (inches), *continued*

NORTH-WEST EUROPE (*continued*)

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Germany.														
Emden	26	2·1	1·6	2·0	*1·6*	2·0	2·4	3·2	**3·4**	*2·4*	**2·9**	2·4	2·5	28·5
Hamburg	85	2·0	*1·7*	2·1	1·8	2·0	2·4	**3·5**	3·1	*2·2*	**2·6**	2·0	2·2	27·5
Norway.														
Bergen	59	8·5	6·4	5·9	4·1	4·5	*3·8*	5·8	7·5	8·7	**8·9**	8·3	8·5	81·0
Christiansund	59	5·1	3·6	3·2	2·4	2·5	*2·1*	3·1	4·2	5·4	**5·7**	4·8	4·4	46·5
Trondhjem	33	3·3	2·3	2·5	*2·2*	2·3	2·5	2·6	2·6	3·3	**4·3**	3·5	4·3	35·7

CENTRAL EUROPE

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
France.														
Clermont-Ferrand	1,273	1·4	*1·3*	1·7	2·0	2·8	**3·2**	2·5	2·7	2·8	2·3	1·7	1·3	25·4
Lyon	574	*1·5*	1·5	1·9	2·4	3·3	3·3	3·0	3·2	3·0	**3·9**	2·6	1·7	31·3
Grenoble (Ec. Nor.)	712	2·6	2·4	*2·3*	2·5	**3·7**	3·5	*2·8*	3·4	3·3	**4·8**	3·3	2·7	37·5
Besançon	1,020	2·8	*2·3*	3·1	3·2	3·9	4·1	3·9	3·7	4·2	**4·7**	3·5	3·2	42·5
Metz	581	1·9	*1·5*	1·8	1·7	2·0	2·7	**2·7**	2·4	*2·2*	**2·6**	2·2	2·2	25·8
Germany.														
Köln	184	1·8	1·7	2·0	*1·7*	2·1	2·8	**3·3**	2·7	2·1	2·4	2·0	2·3	27·0
Frankfurt a. M.	341	1·5	1·3	1·7	*1·2*	2·0	2·2	**2·7**	2·3	1·9	2·1	1·7	2·0	22·7
Freudenstadt	2,395	5·1	4·7	5·7	*3·9*	4·3	4·8	5·1	4·5	4·0	4·6	5·0	**6·4**	58·0
Nürnberg	1,014	1·1	*1·1*	1·6	1·4	2·3	2·6	**3·1**	2·4	2·0	1·7	1·5	1·7	22·9
Munich	1,739	1·6	*1·3*	1·9	2·8	3·7	**4·8**	4·7	4·0	3·7	2·3	1·7	1·8	34·3
Münster	197	2·3	1·8	2·4	*1·7*	2·2	2·8	**3·6**	3·1	2·3	2·6	2·3	2·8	29·9
Hanover	187	1·7	*1·5*	2·1	1·6	2·1	2·7	**3·3**	2·8	1·9	2·0	1·7	1·8	25·2
Kiel	154	2·1	1·7	2·1	*1·7*	1·8	2·2	**3·2**	3·1	2·2	2·8	2·3	2·4	27·7
Stettin	85	1·5	*1·2*	1·6	1·3	1·8	1·9	**3·0**	2·4	1·8	1·8	1·5	1·7	21·5
Königsberg	26	1·7	*1·4*	1·5	1·5	2·0	2·4	3·4	**3·5**	3·0	2·4	2·3	2·3	27·4
Berlin	161	1·5	*1·3*	1·7	1·4	2·0	2·0	**3·1**	2·2	1·8	1·8	1·6	1·7	22·2
Leipzig	394	1·4	*1·3*	2·0	1·6	2·5	2·6	**3·7**	2·6	2·3	2·0	1·7	1·7	25·3
Breslau	482	1·3	*1·0*	1·6	1·5	2·4	2·4	**3·4**	2·8	2·0	1·5	1·5	1·5	22·9

CENTRAL EUROPE (*continued*)

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Scandinavia.														
Copenhagen	16	1·3	*1·3*	1·5	1·3	1·5	1·8	2·3	**2·6**	1·8	2·1	1·7	1·8	20·7
Oslo (Christiania)	82	1·1	*1·1*	1·3	1·3	1·7	1·9	2·9	**3·5**	2·3	2·6	1·9	1·7	23·2
Röros	2,100	1·1	0·9	0·8	*0·5*	1·0	1·8	2·7	**2·8**	1·8	1·3	1·0	1·0	16·5
Östersund	1,010	0·9	*0·9*	0·9	0·9	1·5	2·0	2·2	**3·0**	2·0	1·5	0·9	1·2	17·8
Hernosand	49	1·5	1·1	1·5	*1·0*	1·7	1·7	2·4	**3·1**	2·7	2·7	2·1	1·7	23·2
Switzerland.														
Basel	909	*1·5*	1·5	2·0	2·6	3·2	**4·1**	3·5	3·4	3·1	3·2	2·4	2·0	32·5
Geneva	1,329	*1·6*	1·8	2·1	2·6	3·2	3·0	3·1	3·5	*3·1*	**4·4**	3·1	2·2	33·7
Lucerne	1,480	*1·7*	2·0	2·8	3·7	4·8	5·8	**6·3**	6·1	4·4	3·9	2·5	2·3	46·3
Altdorf	1,480	*2·1*	2·5	3·1	3·9	4·1	5·3	**6·5**	6·0	4·6	4·6	3·5	3·3	49·0
Andermatt	4,741	3·8	**4·2**	3·5	*3·2*	3·4	3·5	4·3	4·7	5·5	**5·6**	3·1	*2·9*	47·7
Sion	1,772	1·7	1·8	1·9	*1·5*	1·7	1·8	2·4	**3·0**	2·1	2·6	2·3	2·3	25·1
Sargans	1,663	*2·3*	2·6	3·1	3·5	4·4	5·6	**6·9**	6·3	5·2	4·6	2·9	2·9	50·3
Säntis	8,202	5·7	6·7	6·7	8·1	7·8	11·2	**12·3**	10·8	8·3	7·2	*4·8*	6·1	95·7
Davos	5,121	*1·8*	2·2	2·2	2·2	2·3	4·0	4·9	**5·0**	3·7	2·7	2·2	2·5	35·7
Bevers	5,610	1·4	*1·0*	1·6	2·2	2·6	3·4	4·3	**4·3**	4·2	3·5	2·4	1·8	32·7
Danube States.														
Innsbruck	1,870	1·6	*1·4*	2·0	2·3	2·9	4·0	**4·8**	4·2	3·3	2·2	1·9	2·1	32·8
Ischl	1,532	3·6	*3·5*	4·6	4·4	5·8	7·4	**8·7**	8·5	5·6	4·1	3·8	4·7	64·8
Klagenfurt	1,444	1·5	*1·3*	2·3	2·6	3·8	4·2	**4·8**	4·6	4·1	4·2	3·1	2·2	38·7
Vienna	666	1·5	*1·3*	1·8	2·0	2·8	**2·8**	2·8	2·8	1·7	1·9	1·6	1·7	24·5
Buda-Pest	367	1·4	*1·1*	1·7	2·0	**2·8**	2·5	2·0	1·9	1·8	2·2	1·9	1·8	23·1
Agram	476	1·8	*1·7*	2·3	2·8	3·5	**3·9**	*3·1*	3·3	3·1	**4·2**	3·1	2·2	35·1
Debreczin	423	1·5	*1·1*	1·6	1·7	2·5	**3·1**	3·1	2·3	*1·5*	**2·4**	1·9	1·7	24·5
Szegedin	312	1·3	*1·1*	1·4	1·9	2·4	**2·6**	2·1	1·9	*1·6*	**1·9**	1·7	1·5	21·5
Belgrade	459	*1·2*	1·3	1·6	2·3	2·8	**3·2**	2·7	1·9	*1·7*	**2·2**	1·7	1·7	24·4
Usküb	804	1·1	1·5	*0·8*	2·0	**2·2**	2·2	*1·3*	**1·6**	1·3	**2·0**	1·9	1·7	20·1

MEAN RAINFALL (inches), *continued*

CENTRAL EUROPE (*continued*)

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Danube States (continued)														
Hermanstadt	1,345	*0·9*	1·0	1·6	2·0	3·4	**4·5**	4·2	3·1	1·9	1·5	1·4	1·1	26·7
Bukarest	295	1·2	*1·1*	1·7	2·0	2·5	**3·3**	2·8	1·9	*1·5*	1·5	**1·9**	1·7	23·0
Braila	98	1·5	*0·8*	1·2	1·3	1·8	**2·6**	1·8	*1·0*	1·1	**1·3**	1·1	1·1	16·7
Sofia	1,814	1·5	*1·4*	1·5	2·0	**3·4**	3·2	2·7	2·1	*1·9*	**2·4**	1·9	1·4	25·9
Poland, E. Baltic States.														
Cracow	1,050	*1·0*	1·1	1·4	1·7	2·6	3·5	**3·6**	3·3	2·3	1·9	1·5	1·5	25·2
Posen	217	1·1	*0·9*	1·3	1·4	2·2	1·9	**3·0**	2·1	1·8	1·4	1·3	1·4	20·0
Warsaw	390	1·3	*1·3*	1·5	1·5	2·0	2·8	**3·0**	2·9	1·9	1·8	1·5	1·5	23·0
Riga	43	1·3	*1·0*	1·1	1·2	1·7	2·4	**3·0**	2·8	2·1	2·1	1·9	1·4	22·0
THE MEDITERRANEAN LANDS														
Spain and Portugal.														
Santiago	863	7·0	6·4	6·0	5·0	5·0	2·8	*1·9*	2·2	4·6	6·7	7·0	**7·3**	62·0
Lisbon	312	3·5	3·4	3·5	2·9	2·0	0·8	*0·2*	0·2	1·5	3·1	**4·5**	4·1	29·7
Gibraltar	49	4·3	*3·5*	**4·4**	2·8	1·7	0·4	*0*	0·1	1·2	3·3	4·5	**6·1**	32·3
Murcia	138	1·2	*1·1*	1·4	**1·4**	1·3	0·7	*0·2*	0·2	1·8	**1·9**	1·7	1·5	14·5
Barcelona	69	1·4	1·3	1·7	2·0	1·5	1·3	1·1	1·4	3·0	3·0	1·8	1·7	14·5
Valladolid	2,346	1·0	*0·9*	1·1	1·1	**1·6**	1·1	*0·4*	0·4	1·3	1·3	**1·4**	1·0	12·5
Madrid	2,149	1·3	*1·1*	1·7	**1·9**	1·7	1·2	0·5	*0·4*	1·3	1·8	**1·9**	1·6	16·4
Seville	98	2·6	*2·0*	**2·6**	1·8	1·7	0·6	*0*	0·1	0·8	2·4	**3·1**	2·5	20·3
France.														
Montpellier	95	3·1	2·7	2·4	*2·3*	**2·8**	1·8	*0·9*	2·0	3·0	**4·1**	3·4	2·4	30·9
Marseilles (Obs.)	246	1·9	*1·4*	1·6	1·7	**1·9**	1·0	*0·6*	0·9	2·5	**4·0**	3·1	2·0	22·6
Nice (Ec. Nor.)	59	2·5	*2·2*	**2·7**	2·2	2·4	1·6	*0·6*	0·9	2·4	**5·8**	4·4	3·1	30·9

THE MEDITERRANEAN LANDS (*continued*)

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Italy.														
Milan	482	2·4	*2·3*	2·7	3·4	**4·1**	3·3	*2·8*	3·2	3·5	**4·7**	4·3	3·0	39·8
Padua	102	2·1	*1·9*	2·4	3·0	3·4	**3·4**	*2·5*	2·6	3·0	**3·8**	3·3	2·5	33·9
Genoa	177	4·2	4·2	4·1	4·1	3·5	2·8	*1·7*	2·4	5·0	**7·8**	7·5	4·8	52·0
Florence	240	2·7	*2·5*	3·0	**3·1**	3·1	2·2	*1·4*	2·0	3·3	**4·3**	4·0	3·2	34·8
Rome	164	3·1	2·5	2·7	2·7	2·3	1·6	*0·7*	1·1	2·8	**4·6**	4·6	3·5	32·3
Naples	489	3·5	2·8	2·9	2·6	2·0	1·3	*0·6*	1·1	2·8	4·5	**4·6**	4·4	33·0
Palermo	233	3·2	2·7	2·8	1·9	1·1	0·6	*0·2*	0·4	1·8	3·2	3·3	**3·7**	25·0
Balkan Peninsula.														
Trieste	98	2·4	*2·3*	2·9	3·0	3·7	**4·0**	*3·1*	3·6	4·8	**6·1**	4·1	3·0	43·0
Ragusa	49	6·8	5·0	5·4	4·8	3·5	2·8	*1·3*	2·6	4·3	7·7	**7·8**	7·2	59·2
Corfu	98	6·4	5·6	4·2	2·9	2·1	1·0	*0·2*	0·9	3·5	6·0	8·1	**9·4**	50·4
Athens	351	2·0	1·5	1·3	0·8	0·7	0·6	*0·3*	0·4	0·6	1·7	**3·0**	2·4	15·4
Salonika	128	1·5	*1·4*	1·6	1·9	**2·4**	1·7	*1·0*	1·2	1·6	2·1	**2·7**	2·4	21·5
Constantinople . . .	230	3·4	2·7	2·4	1·7	1·2	1·3	*1·1*	**1·7**	2·0	2·5	4·0	**4·8**	28·9

PART V

NORTH AMERICA (EXCLUDING MEXICO)

CHAPTER XXXII

GENERAL FEATURES

North America is the second largest of the land masses of the Earth, but its area is less than half that of Asia. The continent is compact in form. The only large inland sea is Hudson Bay, a shallow basin, ice-covered much of the year. The Great Lakes are much smaller but they are not frozen over in winter, and perhaps for this reason they have not less influence on the climate of the continent than Hudson Bay. On the west coast the continent lacks large indentations, and thus presents a great contrast to Eurasia. Another important difference is the trend of the main feature lines. The Rocky Mountain system runs from north to south, the mountain ranges of Eurasia from west to east, and the greater continuity of the former causes them to be a very important climate barrier although they are less lofty than the mountains of Eurasia. Rising steeply from the Pacific Ocean, and consisting of several parallel ranges and intermont basins with a total width of 500 miles in Canada and as much as 1,000 miles in the States, the system is a formidable rampart in the way of the prevailing westerly winds. On the east the mountains fall sharply to the high plains, in places 6,000 feet above the sea, and the high plains slope gradually down to the vast lowland centre of the continent which includes Hudson Bay, the western part of the Great Lakes, and the Mississippi valley, and affords a wide open passage from the frozen wastes of the north of Canada to the subtropical shores of the Gulf of Mexico. There is no transverse barrier. The gently rolling lowlands are highest in the neighbourhood of the international frontier, but it is possible to go from the Barren Lands to the Gulf without rising above 1,000 feet. The Appalachian system

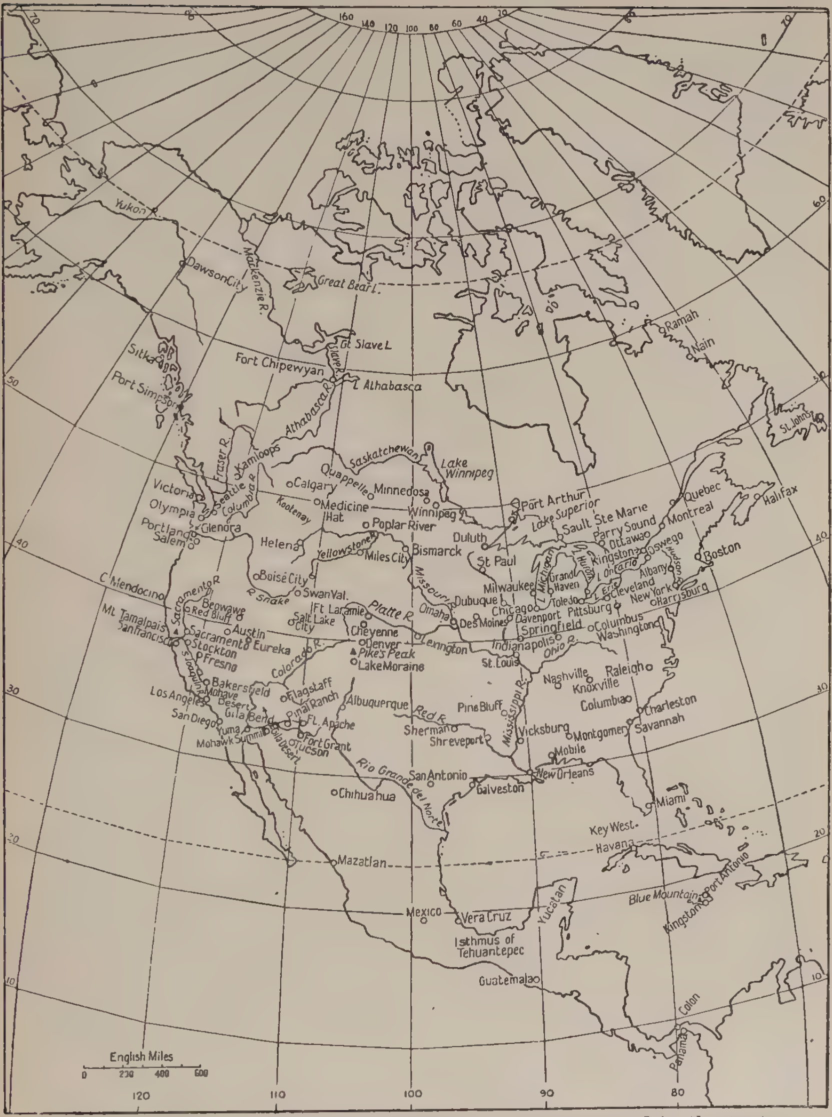

160
140
120
100
80
60
40
20
70
60
50
40
30
20
10
Yukon
Dawson City
Mackenzie R.
Great Bear L.
Gt Slave L
Slave R.
Sitka
Port Simpson
Fort Chipewyan
L Athabasca
Athabasca R.
Fraser R.
Kamloops
Saskatchewan
Lake Winnipeg
Quappelle
Minnedosa
Calgary
Victoria
Seattle
Columbia R.
Kootenay
Medicine Hat
Winnipeg
Olympia
Glenora
Portland
Salem
Poplar River
Port Arthur
Lake Superior
Sault Ste Marie
Parry Sound
Ottawa
Quebec
Montreal
Halifax
St Johns
Ramah
Nain
Helena
Yellowstone
Miles City
Bismarck
Duluth
St Paul
Kingston
Oswego
L Ontario
Boston
Hudson R.
Boisé City
C. Mendocino
Sacramento R.
Beowawe
Red Bluff
Snake
Swan Val.
Ft Laramie
Platte R
Missouri
Omaha
Dubuque
Milwaukee
L. Michigan
Grand Haven
L. Huron
Toledo
L. Erie
Cleveland
Albany
New York
Harrisburg
Mt. Tamalpais
San Francisco
Sacramento
Stockton
Austin
Eureka
Salt Lake City
Cheyenne
Denver
Pike's Peak
Lake Moraine
Lexington
Des Moines
Chicago
Davenport
Pittsburg
Springfield
Columbus
Washington
Indianapolis
Ohio R.
Fresno
San Joaquin
Colorado R.
St. Louis
Nashville
Knoxville
Raleigh
Bakersfield
Mohave Desert
Los Angeles
San Diego
Gila Bend
Flagstaff
Pinal Ranch
Albuquerque
Red R.
Pine Bluff
Mississippi R.
Columbia
Charleston
Savannah
Yuma
Mohawk Summit
Gila Desert
Ft. Apache
Fort Grant
Tucson
Sherman
Shreveport
Vicksburg
Montgomery
Mobile
Rio Grande del Norte
San Antonio
Galveston
New Orleans
Chihuahua
Miami
Key West
Havana
Mazatlan
Blue Mountain
Port Antonio
Kingston
Mexico
Vera Cruz
Yucatan
Isthmus of Tehuantepec
Guatemala
Colon
Panama
English Miles
0
200
400
600
120
110
100
90
80

FIG. 98. Key map, showing the position of places named in the text.

and the heights of northern Quebec are much lower and less continuous than the western mountains, and have little influence on the climate of the surrounding country.

The lowlands of Europe, on the other hand, are situated in the west as well as in the north, and no mountain barrier cuts them off from the ocean, which is able to extend its moderating influence far to the east, assisted by the bordering seas in the north and south of the continent. But the north and south of Eurasia are climatically severed, especially in Asia, by the east to west feature lines of the tertiary mountain folds, and the elevated plateaux of the heart of the continent.

Oceanic conditions. The North Pacific Drift impinges on the west coast of the continent. It is a continuation of the Kuro Siwo current, the counterpart of the Gulf Stream of the Atlantic Ocean but much less powerful, owing partly to the less volume of warm water in proportion to the size of the Ocean which the equatorial currents pour into the North Pacific, and partly to the shape of the basin, which is almost closed in the north. The Drift, wafted from west to east by the westerlies, meets the American coast in the neighbourhood of the mouth of the Columbia River, and divides ; one branch flows northward and brings to British Columbia its mild winters ; the other, known as the California current, flows southward as a cool current which greatly modifies the climate of the coast, causing low temperatures, scanty rainfall, but much summer fog ; it corresponds to the Canaries current off North-west Africa.

On the east coast the Labrador current is of great importance from Baffin Bay to Newfoundland. It carries along enormous volumes of Arctic water and great masses of ice, much of which does not melt till it reaches the warm Gulf Stream on the Grand Banks. The very cool summer of Labrador is due to this current which chills the on-shore winds. The Labrador current can be traced far south as the Cold Wall close along the United States coast, but here its climatic importance is not great, since its width is small, and it is overshadowed by the Gulf Stream. The Gulf Stream is a great current of very warm water, which flows along near the American coast from the south of Florida to Newfoundland. The direct climatic benefit which America derives from it is not nearly so great as might be expected, since in winter, when a warm current can have most effect in temperate latitudes, the prevailing winds are off-shore ; thus, even in the coastal belt, the rigorous winters are not much ameliorated by the warm water. In summer the on-shore winds blow over it and become hot and moist. When these qualities are specially intense the winds are known as ' hot waves ', which are an unpleasant element in the climate of the eastern states. The Gulf of Mexico, from which part of the Gulf Stream flows, is always warm, and the air over it is charged with abundant moisture. This explains the heavy rainfall of the south of the United States. In winter the warm moist air over the Gulf is conducive to low-pressure conditions, and hence to the spread of ' cold waves ' from the centre of the continent to its subtropical shores.

CHAPTER XXXIII

PRESSURE AND WINDS

We have already seen that Eurasia greatly modifies the planetary pressure belts and develops over itself the highest atmospheric pressures known on the globe in winter, and very low pressures in summer. The resulting monsoonal wind reversal is remarkably complete. In North America there are similar but much less marked seasonal changes. In January (Fig. 99) the subtropical belt of high pressure spreads northward over the cold continent, especially over the western part, and invades the planetary low-pressure belt of temperate latitudes, which it divides into the ' permanent ' low-pressure systems of the North Atlantic and North Pacific Oceans. The mean barometric gradient is steepest over the north-west of the continent. The continental high-pressure system is not nearly so intense nor so permanent during the winter as that over Eurasia, since it is constantly liable to modification by the cyclonic activity which is remarkably great over North America; indeed there is an almost unbroken procession of cyclones and anticyclones rather than a permanent stationary high-pressure system. Cyclones are probably more numerous than in any other continent. Their speed is about twice as great as in Europe, and the absolute barometric pressure is greater. They almost always alternate with well-developed anticyclones, and in this respect present a contrast to the cyclones of north-west Europe, which are but rarely accompanied by anticyclones. The resulting weather over North America is changeable. Sometimes a single cyclone or anticyclone may dominate the weather from Hudson Bay to the Gulf of Mexico, and owing to the absence of a transverse mountain barrier the winter temperature of north Canada or the summer heat of the Gulf may spread over much of the continent, modified of course with distance, but very perceptible.

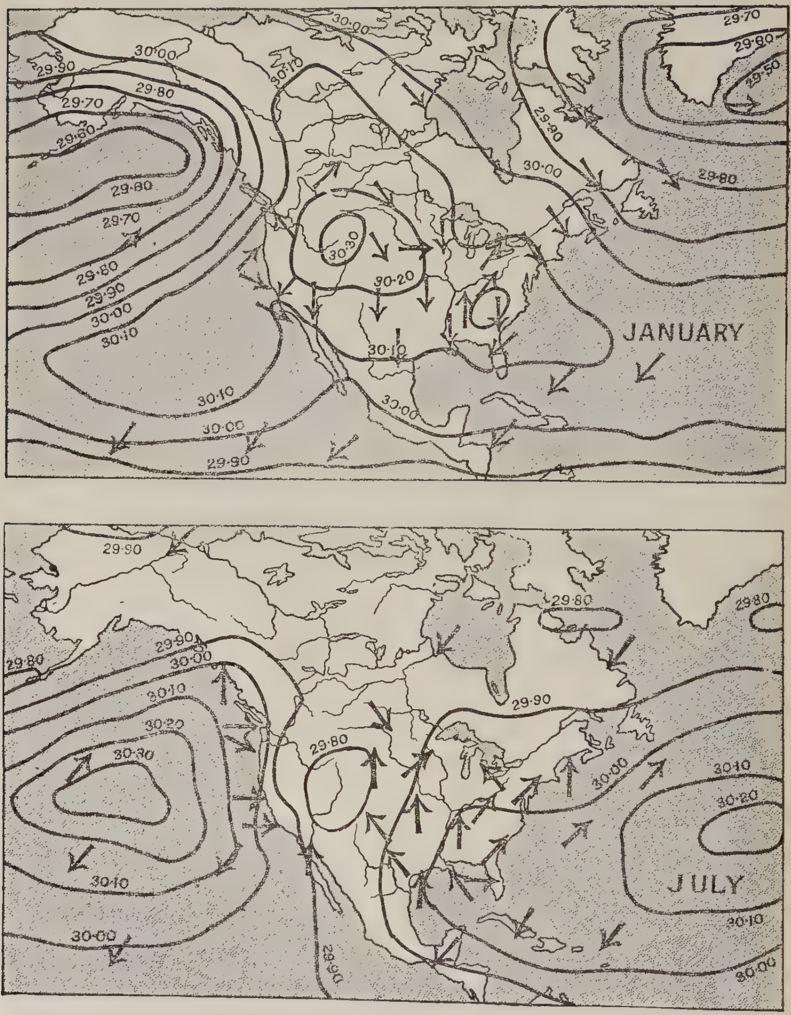

30·00
29·70
29·80
29·50
30·00
29·90
30·10
29·80
29·70
29·60
29·80
29·70
30·30
30·20
29·80
29·90
30·00
29·80
30·10
30·10
JANUARY
30·10
30·00
30·00
29·90
29·90
29·80
29·80
29·90
30·00
30·10
30·20
30·30
29·80
29·90
30·00
30·10
30·20
30·10
JULY
30·00
30·10
29·90
30·00

FIG. 99. Mean pressure and prevailing winds.

In winter most of the continent is within the belt of the westerlies, which are much modified by the continental influence but not nearly so much as in Asia. In the east of Canada and the United States the prevailing winds are west and north-west, the high pressures over the continent reinforcing the planetary winds. The Missouri and Mississippi valleys, being on the east and south of the high-pressure system, have north winds. North winds prevail on the shores of the Gulf of Mexico also; but on the coast of Texas, especially the western part, the winds are variable, and at some stations, Galveston for example, the prevailing direction is south-east in January. The region between the Appalachians, the Mississippi, and the Great Lakes is exceptional in having south-west winds in winter and in summer, caused in winter by a detached high-pressure system over the south-east of the States. But these prevailing winds are much less constant than those of Asia, since there is frequent veering and backing under the influence of the numerous cyclones and anticyclones.

The direction of the wind on the Pacific coast shows that either the western mountain barrier, or the continental high pressures, or both, present an effective obstacle to the westerlies. North of the fortieth parallel the prevailing winds are south and south-west, on the coast of British Columbia south-east, blowing along and somewhat off shore. They form the inflow on the east side of the North Pacific depression, and correspond to the south-west winds of the British Isles, being like them rainy and mild. But they are confined to the narrow littoral of British Columbia, since the mountains prevent that great landward extension of oceanic conditions which is such a valuable climatic asset in the case of Europe. On the coast of Oregon the winds are variable, south and west being the most frequent directions; in the south of California they become north-west, and finally north in Lower California under the influence of the North Pacific anticyclone; these latter are really trade winds, as are also the easterly winds of south Florida and the Gulf of Mexico.

With the approach of spring the high pressures over the continent become less intense, and by April they have almost disappeared. The isobars for May show the commencement of the summer conditions which culminate in July (Fig. 99). As in the case of Eurasia the land mass is warmer than the sea and pressure is low, the high-pressure subtropical belt being now interrupted by the continent, which is covered by a trough of low pressure connecting the low pressures of the Equator and the temperate zone; but the low pressures over North America are neither so deep nor so constant as those of Asia. The North Atlantic anticyclone is a prominent feature on the isobar map and spreads over much of the south-east of the States; still more prominent is the anticyclone over the North Pacific, whose influence dominates the weather of the whole of the west coast of the continent from the south of California to Alaska.

WIND-DIRECTION, PERCENTAGE OF ALL OBSERVATIONS

		N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calms.*
Portland	Jan. .	7	*6*	11	19	19	10	6	**21**	1
(Ore.)	July .	10	*2*	3	8	8	8	6	**54**	3
San Fran-	Jan. .	**25**	6	*5*	19	7	9	10	20	0
cisco	July .	1	1	*0*	1	2	**53**	**41**	1	0
New York	Jan. .	8	13	6	*4*	6	15	18	**30**	0
	July .	*5*	9	6	10	19	**24**	12	16	0
Galveston	Jan. .	15	15	13	**20**	13	7	*4*	12	0
	July .	*3*	4	5	30	**33**	18	4	3	0

PREVAILING WINDS

	January.	*July.*		*January.*	*July.*
Los Angeles .	NE.	W.	Reno . . .	W.	W.
Key West . .	NE.	E.	Pikes Peak . .	W.	SW.
Charleston . .	N.	SW.	St. Paul . .	NW.	SE.
Eastport (Maine).	NW.	S.	Chicago . .	SW.	SW.
New Orleans .	N.	SE.	Cincinnati . .	SW.	SW.

The winds in the east and south of the continent show a monsoonal change from the winter direction, but except in Texas there is not a complete reversal. On the east coast they blow from the south-west, on the coast of the Gulf of Mexico from the south-east; in Texas there is a complete monsoonal change from north in winter to south in summer. On the Pacific coasts the wind shows a marked tendency to blow into the continent, from the west in British Columbia, from the north-west in Washington and Oregon, where it is said to blow almost with the constancy of the trades. California has trade winds, blowing from the north; the local topography, however, gives San Francisco almost constant south-west and west winds. The North Pacific anticyclone controls the weather and winds of almost all this coast, the low-pressure system which lay over the northern part of the ocean in winter having practically disappeared from the map. Hence there is very little rain in summer. But in the centre and east of the continent cyclonic activity still goes on.

As an indication of the extent of the monsoonal change in North America and Asia respectively the following figures, calculated by Hann, are instructive. They express the frequency of the various wind directions as percentages of all observations.

	N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*
N.E. Asia.								
Winter . . .	17	8	5	6	6	8	18	32
Summer . .	10	9	12	26	16	10	7	10
E. coast, N. America.								
Winter . . .	11	15	6	6	7	18	14	23
Summer . .	8	12	6	11	13	28	9	13

The more variable winds and less complete change from summer to winter in North America shown by these figures are no doubt due partly to the smaller area of the continent, but chiefly to the absence of a transverse barrier to separate the cold dry air of the north from the moist warm air over the Gulf of Mexico. When currents of air endowed with such opposite qualities come together atmospheric disturbances are produced, and develop into cyclones and anticyclones from which variable winds result. Perhaps the barring of the westerlies by the western mountain system which lies athwart their course may conduce to the same result.

CHAPTER XXXIV

TEMPERATURE

In January (Fig. 100) almost all Canada, and the northern third of the United States have a mean temperature below 32°. The 50° isotherm skirts the northern shores of the Gulf of Mexico, and the 70° isotherm appears over the southern point of Florida. The north of Canada is the coldest part of the continent, with a mean below −30° F.

The isotherms swing farthest to the south over the Mississippi valley, and trend northward somewhat as they approach the east coast; thus the 30° isotherm passes through St. Louis, and reaches the east coast at Long Island. In the west the isotherms diverge

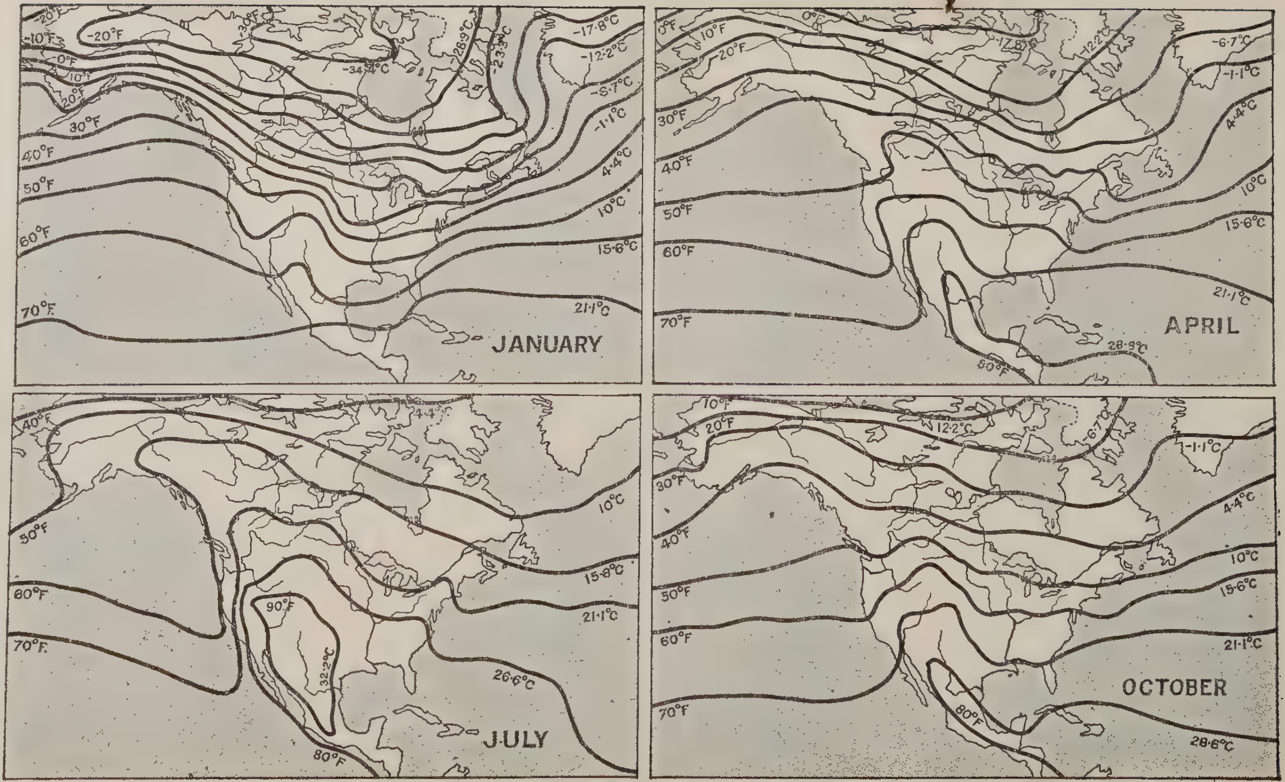

JANUARY
-20°F
-10°F
0°F
10°F
20°F
30°F
40°F
50°F
60°F
70°F
-30°F
-34·4°C
-28·9°C
-23·3°C
-17·8°C
-12·2°C
-6·7°C
-1·1°C
4·4°C
10°C
15·6°C
21·1°C
APRIL
0°F
10°F
20°F
30°F
40°F
50°F
60°F
70°F
80°F
-17·8°C
-12·2°C
-6·7°C
-1·1°C
4·4°C
10°C
15·6°C
21·1°C
28·9°C
JULY
40°F
50°F
60°F
70°F
80°F
90°F
32·2°C
4·4°C
10°C
15·6°C
21·1°C
26·6°C
OCTOBER
10°F
20°F
30°F
40°F
50°F
60°F
70°F
80°F
12·2°C
-6·7°C
-1·1°C
4·4°C
10°C
15·6°C
21·1°C
28·6°C

FIG. 100. Mean Temperature. (Buchan.)

from the parallels of latitude in a very striking way. Near the coast they have a north-west to south-east trend, almost parallel with the coastline; evidently the warm waters of the ocean are as important a source of heat as direct insolation. In Vancouver Island we find the 40° line running from north to south, much as in the British Isles. The cold increases rapidly as we strike inland, and we reach the 32° isotherm within 40 miles, the warm oceanic conditions being shut off from the interior by the mountain ranges. In Europe in the same latitude the 32° isotherm is 500 miles eastward from the ocean.

British Columbia enjoys the mild and moist climate of North-west Europe on its coasts, but immediately behind the Coast Range, on the Fraser River, the climate is that of Central Europe. Victoria (Vancouver Island) has a mean temperature in January of 39°, New Westminster 35°, Kamloops, 250 miles from the open Pacific and half-way from the coast to the Rockies, 22°. Latitude for latitude the coast is not quite so warm as that of west Europe; at Sitka (lat. 57° N.) the mean is 30°, at Portree, Scotland (lat. 57½° N.), 39°.

East of the Rockies we enter an extreme continental climate. At Calgary the mean temperature in January is 11°. The altitude of the high plains in this neighbourhood is over 3,000 feet, and there is a steady descent eastward, but in spite of this the temperature becomes less and less, for the increasing distance from the Pacific Ocean more than neutralizes the decrease in altitude. The mean temperature is 12° at Medicine Hat (2,160 feet), −1° at Qu'appelle (2,115 feet), −1° at Minnedosa (1,400 feet), −3° at Winnipeg (760 feet). But the warmth of the high plains at the eastern foot of the Rockies is the result not only of proximity to the ocean, but also of the 'chinook winds'. These are dry and warm west winds of the föhn type, which owe their qualities to compression as they descend the leeward slope of the mountains. Their influence is confined to the country along the east foot of the range, where they rapidly melt and dry up the snow, and enable grazing to go on all the winter. They are an important factor in the climate from the south of Colorado northward as far as settlement has advanced in Canada. The rise in temperature when the chinook sets in is sometimes exceedingly rapid, as much as 40° in 15 minutes being occasionally recorded. As a rule the temperature does not exceed 40°, but this appears very warm after the intense cold which may have prevailed during a preceding spell of anticyclonic weather.

In the United States there is a similar decrease in temperature from the high plains to the Mississippi valley:

	Altitude. Feet.	*Mean Temp. Jan.*		*Altitude. Feet.*	*Mean Temp. Jan.*
Cheyenne	6,088	26	Des Moines	861	20
Lexington	2,385	25	Davenport	580	21
Omaha	1,103	20	Chicago	824	24

Manitoba is the coldest part of the continent in winter for its latitude. Farther east near the Great Lakes temperature rises rapidly, and on the northern shores of Lake Superior we find a January mean of 10°. The warmest part of Canada in winter, excluding the west coast, is Peninsular Ontario, which lies farthest south, and is most subject to the warming influence of the lakes. Eastward from the lakes the mean temperature at first becomes lower and then higher again near the east coast. The January mean at Ottawa is 12°, at Halifax 24°. These means are not comparable with that for Winnipeg, which is farther north, but even the bleak coast of Labrador is warmer than the interior of Canada; inhospitable summers rather than specially cold winters are the most unpleasant feature of the climate of Labrador.

It is instructive to examine the influence of the Great Lakes on their neighbourhood in more detail. They cause a slight northward bend in the isotherms in October owing to the retention of the summer heat by the water mass, and the bend becomes more and more pronounced till January, after which it diminishes; in March the lakes probably cease to act as a source of warmth. The east shores are more warmed by the lakes than the west owing to the prevailing westerly winds. At Milwaukee, on the west shore of Lake Michigan, the mean January temperature is 20°, the absolute minimum -25°; at Grand Haven on the opposite shore the mean is 25°, and the absolute minimum only −12°; at Dubuque, 160 miles west of the lake, −32° has been registered. Duluth, at the western end of Lake Superior, has a mean temperature in January of 10°, absolute minimum -41°; at Sault Ste. Marie the corresponding figures are 15° and −28°. A strip of country, 20 to 30 miles wide, along the east shore of Lake Michigan, is known as the ‘ Fruit Belt ’, because the lake so ameliorates its climate that peaches, grapes, and other tender fruits are cultivated with a success which is impossible in other districts in the same latitude not similarly favoured. Lake Erie warms its shores in the same way ; the lowest temperature ever recorded at Toledo, on its south shore, is −16°, but Columbus, 100 miles south of the lake, has recorded −20°.

The lakes are usually frozen along the shores in winter, and the melting of the ice delays the coming of spring. In summer the water cools the neighbourhood, but not so much as it warms it in winter ; ‘ land ’ and ‘ sea ’ breezes are a usual phenomenon on the shores. ‘ The Grape Belt which extends along the southern shore of Lake Erie for a distance of about 60 miles, and is from 2 to 6 miles wide, has the most temperate climate in New York State except the region along the Atlantic coast. This is directly due to the tempering influence of the lake, which holds vegetation in check in the spring until danger from frost is over, gives long mild autumns with unusually late fall frosts, and winters much less severe than elsewhere. The tempering influence of the lake is noticeable for a distance of about 30 miles inland ’ (*Climatological data for the United States*). The effect of Lake Ontario is important especially when cold waves at very low temperatures sweep down from Canada, the difference in temperature between the north and south sides of the lake at such times amounting frequently to 20° (*Ibid*).

The coldest part of North America in winter is the tract between Hudson Bay and Alaska. The north coast, and the numerous islands between it and the Arctic Ocean, are not quite so cold, since even the ice-covered sea provides more warmth, despite its higher latitude, than the northern interior of the continent during the Polar night. There the cold is intense, but not so intense as in north-east Siberia. The Great Bear Lake is covered with ice 8 feet thick, much of which remains unmelted throughout the year. In the neighbourhood of the Mackenzie River the temperature probably falls at times to −75° ; and the mean monthly temperature is below freezing-point for 8 months out of the twelve. But the air is dry and calm, and the weather often beautifully fine and exhilarating. At Dawson City −69° has been recorded ; the river Yukon freezes in September and remains frozen till May.

On the west coast of Alaska the temperature is much higher, but still far below freezing-point; owing to the damp and often foggy air the climate is less pleasant than in the interior.

The warmest part of the continent is the lower Colorado valley. At Yuma, 141 feet above the sea, the mean temperature in January is 55°, and 81° has been recorded in that month, but, as is usual in an arid climate, the nights are often cold and a reading of 22° has been observed. On the higher plateaux in this district the nights are far colder; 10° has been recorded at Fort Grant, Arizona, 4,916 feet above the sea, where the clear dry air favours very rapid radiation of heat. On the plateaux of Oregon, Washington, and the north of Nevada and Utah it is much colder than in Arizona in winter. Swan Valley, Idaho, 5,434 feet above the sea, has a mean temperature in January of 21°, and has recorded a reading of −35°. But the minimum readings are not so low as those found east of the Rockies, where the altitude is less; Fort Laramie, on the north Platte River in Wyoming, 4,270 feet above the sea, but situated in a valley bottom, has recorded −48°. The lowest minima in the country lying immediately to the east of the Rockies are always recorded in the bottoms of the valleys. The absolute minimum for the whole of the United States is −65°, at Miles City in the south-east of Montana, a town in the bottom of the Yellowstone valley, 2,371 feet above the sea. Poplar River, another station in a very similar situation in the same state, has reported −63°. The plateaux and mountain summits have lower mean temperatures, as might be expected from their greater elevation, but the absolute minima are not so low. Lake Moraine, Colorado, 10,265 feet above the sea, has no record below −31°, and even Pikes Peak, 14,134 feet, none below −39°. Clearly the very low readings in the valley bottoms are the result of the drainage of the coldest air to the lowest ground, giving an inversion of temperature. The Pacific littoral is notably warmer than the Atlantic, but even San Diego has recorded 25°. The extreme south of Florida is the only part of the continent (excluding Mexico) which has never recorded frost (Fig. 101).

No account of the American winter would be complete without a reference to the 'cold waves'. We have already mentioned the great cyclonic activity in the continent. As they travel east the pressure systems sometimes become elongated in a north–south direction and form a long belt of high or low pressure, which causes northerly currents of air to sweep over great expanses of country from north to south (Fig. 102). They often originate in the north-west of Canada where the clear skies of an anticyclone may be causing rapid radiation, and consequently great cold, and as they advance southward they bring Canadian cold, modified somewhat by the southward journey, even to the coasts of the Gulf of Mexico. They are an important factor in causing the variable weather for which the States are noted. The rapidity of the weather changes is due to the rapid movement of the cyclones. The warm inflow from the south in front of a depression is of almost as pronounced a character as the cold wave which suddenly takes its place when the trough of the depression has passed. Cold waves are coldest in the north of the United States. In the mid-course of the Mississippi the extremes are not so great, but the changes are especially noteworthy since the temperature often drops suddenly from well above, to well below, freezing-point, and such a change entails the maximum of inconvenience and discomfort. St. Louis has recorded 74° and −22° in

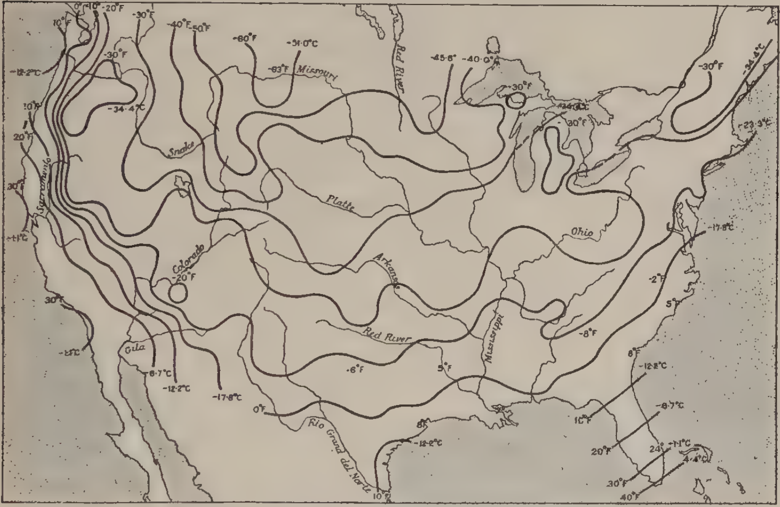

0°F
-10°
-20°F
10°F
-30°F
-40°F
-50°F
-60°F
-51·0°C
-30°F
-63°F
Missouri
Red River
-45·6°
-40·0°C
-30°F
-34·4°C
-30°F
-30°F
-34·4°C
-12·2°C
-34·4°C
10°F
20°F
Snake
Sacramento
30°F
Platte
-23·3°C
-1·1°C
Colorado
-20°F
Arkansas
Ohio
-17·8°C
30°F
-2°F
5°F
-1·1°C
Red River
Gila
-6·7°C
-12·2°C
-17·8°C
-6°F
5°F
Mississippi
-8°F
8°F
-12·2°C
0°F
Rio Grand del Norte
8°F
-12·2°C
-6·7°C
10°F
10°F
20°F
24°
-1·1°C
4·4°C
30°F
40°F

Fig. 101. Absolute minimum Temperature.

January, that is to say, 42° above, and 54° below freezing-point. In December 1831 the Mississippi was frozen over for 130 miles below the mouth of the Ohio; the ice at New Orleans was thick enough for skating.

Nearer the Gulf, especially in Texas, cold waves are called Northers. Since the average temperature is fairly high in these parts the cold is severely felt. Sometimes there is sleet or snow, but generally the weather is clear, and the Norther blows as a strong dry north wind for one or more days, with a temperature considerably below freezing-point. At San Antonio the mean temperature in January is 53°, and 83° has been recorded; but during a Norther the thermometer has dropped to 6°. At Galveston on the coast −8° has been recorded.

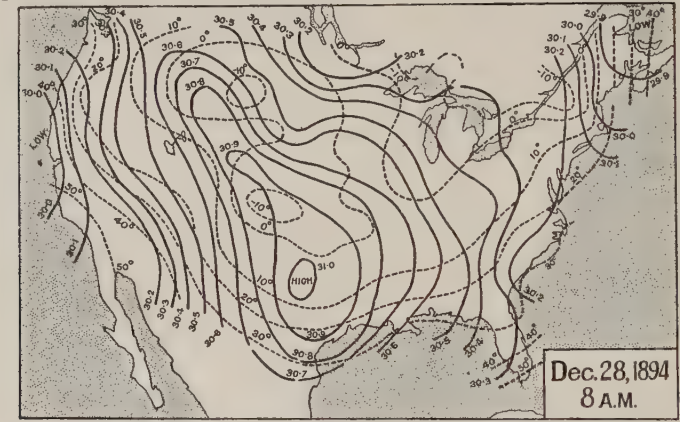


FIG. 102. Pressure and Temperature Conditions during a cold wave in the Mississippi valley and the eastern states. Full lines are isobars, broken lines isotherms, °F.

The Blizzards of the northern States and west central Canada are cold waves of a special type, in which there is a howling gale of wind, and the air is full of dry powdery snow, so that the wayfarer easily loses his bearings. It is impossible to remain alive for many hours without shelter in such conditions. The Blizzard is closely akin to the Buran of Siberia.

Cold waves often reach Florida, and sometimes bring frost almost to the extreme south of that state. Key West, an island off the south coast, alone has never recorded frost, the thermometer not having been known to fall below 41°. Cold waves sometimes appear in a severe form in all the Atlantic States. On the Pacific coasts they are much less important, but they have been felt as far south as the Mexican frontier; they never bring such low temperatures as in the centre and east of the continent. They are keenly felt on the high plateaux of Arizona and New Mexico, and prevent the cultivation of the sub-tropical fruits which are usual crops in California.

We shall conclude our description of the winter temperature conditions with a comparison of the west and east coasts of N. America, with one another, and with the west and east coasts of Eurasia.

West Coast.	*Lat. °N.*	*Mean Jan. Temp.*	*East Coast.*	*Lat. °N.*	*Mean Jan. Temp.*
North America.					
Sitka	57·0	30	Nain	56·5	−7
Victoria	48·5	40	St. John's (Newf'dl'd)	47·5	24
Eureka	41·0	47	New York	41·0	30
San Diego	32·5	54	Savanna	32·5	50
Eurasia.					
Portree	57·5	39	Aian	56·0	−5
Brest	48·5	43	East coast of Siberia	48·5	0
Oporto	41·0	47	Vladivostok	43·0	5
Mogador	32·5	57	Shanghai	31·0	38

The west coast of America is very much warmer than the east in all latitudes, its advantage being greatest in the north. Sitka, Alaska, is never icebound, and is 37° warmer than Nain on the Labrador coast, from which icebergs are to be seen even at midsummer, and continuous icefloes during much of the year. The mean temperatures given for similar latitudes in Eurasia show that on the west coast the Old World is the warmer; the difference is not great in the latitude of California, but it is considerable in the north, Portree being 9° warmer than Sitka. The difference is greater on the east coasts, greatest in the latitude of New York, which is 25° warmer than Vladivostok. This is the result of the more constant monsoonal conditions in East Asia, for there the north-west winds from the cold interior of the continent hardly ever cease to blow in winter, but in the east of America south winds are not infrequent as cyclones approach from the west. Labrador is north of the usual cyclone tracks, and in those latitudes the temperature difference between America and Asia is small, America being the colder.

In July the isotherms bend sharply poleward over the hot land. The 50° line has retreated almost to the north coast of the continent;

over a large area the temperature exceeds 90°. The isotherms, which we must remember denote 'sea-level' temperatures, run considerably farther north in the west of North America than in the east, which shows that the plateaux in the west are unduly warm. In spite of their altitude, or rather, perhaps, because of it, since the air is less dense and therefore offers less obstruction to insolation, the arid and semi-arid uplands are heated strongly during the long summer days. The following table, the temperatures in which are not reduced to sea level, shows that Beowawe, Nevada, is even warmer than Springfield, 4,000 feet lower; the temperature at Austin also is remarkably high for its altitude:

	Alt. Feet.	*Locality.*	*Mean Temp. July.*	*Abs. Max.*
Beowawe	4,695	Humboldt R., Nevada	77	105
Austin	6,594	Plateau, Nevada	69	101
Springfield	609	Mississippi Valley	76	107
St. Louis	568	,, ,,	79	107

In the lowlands of Arizona, the Colorado and Mohave Deserts, temperatures comparable with those of the Sahara are produced by the blazing summer sun shining through the dry air. The highest record for the continent, 134°, occurred on July 10, 1913, in Death Valley, California, where the mean temperature for July is 102°. On the plateau the temperatures are somewhat lower:

	Altitude. Feet.	*Mean Temperature. July.*	*Absolute Maximum.*
Mohawk Summit (Gila R.)	538	98	126
Tucson	2,390	87	112
Fort Grant	4,916	78	106

But the dryness of the air helps to make the intense heat supportable and, moreover, the hot days are followed by cool nights on the higher plateaux; at Fort Grant the thermometer has been known to fall to 48° in July, at Tucson to 55°, but not below 79° at Mohawk Summit. Thus there is a great range of temperature, both annual and diurnal; the latter is greatest in the warmest months.

The course of the summer isotherms on and near the west coast of the United States is very striking, and shows an extraordinarily rapid increase in temperature from the coast towards the interior (Fig. 103). The plateau, as we have seen, is unduly hot for its latitude and altitude, while the coast is abnormally cool owing to the presence of the cold California current, which not only chills the air directly, but also causes much fog, which keeps off the sun's warmth. These sea fogs are essentially a summer phenomenon; their total duration extends over about 50% of the summer hours. Seaward they form a belt along the coast with a width of some 50 miles, and a thickness of 1,500 feet. But they are dissolved before they can penetrate far inland. The fog-belt on the Coast Ranges which rise steeply from the Pacific is the home of the redwood tree, the leaves of which are adapted to condense copious moisture from the fog. Beyond the Coast Ranges is the Great Valley of California, a flat-bottomed depression 400 miles long and 50 miles wide, drained by the River Sacramento in the north, and the San Joaquin in the south. The Great Valley is walled on the east by the lofty Sierra Nevada, which rises to over 14,000 feet. The cool foggy weather of the coast in summer is shut out by the Coast Ranges; San Francisco has a very low mean temperature, 57°, in July, far lower than the coast of Europe in the same latitude; but Bakersfield in the south of the Great Valley has 89°, and Red Bluff in the north 82°. The difference between coast and interior is as great as between Scotland and the north of Africa, though the distance in the case of California is only some 75 miles. The strong sea breeze finds its way into the Great Valley by the opening through which the drainage of the Valley reaches the sea at the Golden Gate, and it spreads to north and south, up the Sacramento and San Joaquin. Its influence on the

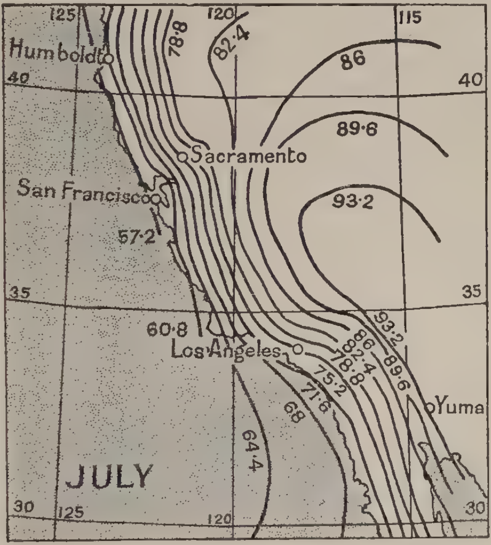


Fig. 103. Mean Temperature in July. (Hann.)

temperature is clearly traceable; Stockton, which is situated opposite the opening to the sea, has a July mean of 73°, and the temperature increases up the Valley both northward and southward to over 80° at Bakersfield and Red Bluff. As we ascend the Sierra Nevada we find an increase in temperature at first in spite of the greater altitude, since we are receding from the sea influence; as the slope becomes steeper the reduction due to altitude asserts itself more strongly, but it has been pointed out that we must rise to 7,000 feet before we reach as low a temperature as at San Francisco.

At San Francisco late September is the warmest part of the year. The long retardation of the maximum is explained by the fact that at midsummer the interior of California is very hot, and a strong sea-breeze sets in through the Golden Gate, and brings the low temperatures of the California current to San Francisco. But in the beginning of autumn the interior is cooling, and the sea-breeze becomes weaker and finally ceases, so that although the sun has already retired to the Equator September is the warmest month.

The summit of Mount Tamalpais, which overlooks San Francisco from the other side of the Golden Gate, is very much warmer than that town in summer, for although its altitude is 2,375 feet, its mean July temperature is 70° (Fig. 104). Its advantage is due to the fact that it rises into bright sunshine, and looks down from above on to the top of the fog layer which so often shrouds the coast; its altitude, too, removes it from the cold sea water. In winter, however, when fog is less frequent, and temperature depends less on the direct rays of the sun, Mount Tamalpais is cooler than San Francisco. The mean annual range of temperature is 25° at the former station, only 10° at the latter.

In winter the Great Valley is cooler than the coast, but the difference is not nearly so great as in summer; frost is common in the interior, and at Fresno the thermometer has fallen to 20°.

California represents the Mediterranean climate region in North America. The Mediterranean of the Old World is recalled both by the rainfall régime, to be described later (p. 292), and the temperature. The contrast between the cool Atlantic coast and the hot interior and east of the Mediterranean region is repeated in an exaggerated form; for the coast of California is much cooler, damper, and foggier than the coast of Portugal, and the Great Valley is even hotter and more sunny than the south of Italy and Greece, the summers being remarkably dry and cloudless. This is partly explained by the fact that California is farther south than the corresponding region in the Old World, partly by the difference in the topography, the Great Valley being continental, Greece and Italy peninsular. The closest parallel to the cool foggy Californian coast is found in Morocco, where, however, the temperature is much higher. Lagos in south-west Spain is almost 20° warmer in January than San Francisco which is in the same latitude. Like the Mediterranean region, south California sometimes experiences hot winds, called Santa Ana, which blow from the deserts in the east, often with great force. They are most frequent in winter, and are exceedingly dry, hot, and dusty.

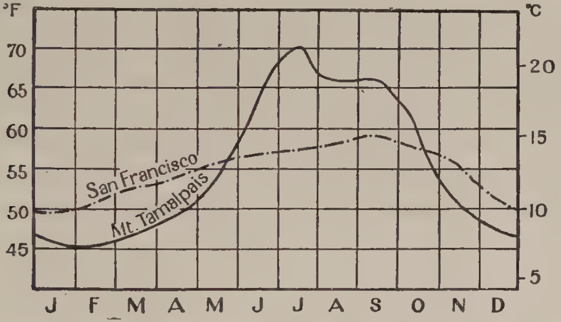


FIG. 104. Mean Temperature at San Francisco (207 feet) and Mount Tamalpais (2,375 feet).

> 'On the coast they are hot and are skin-drying, lip-cracking, unpleasant visitants. In places they pierce window panes with little round holes as if drilled by the coarse gravel they carry like a dose of small shot. If they come in the spring after the first blooms form, both the bloom and the young fruit drop off the trees after a short time.' (*Climatological data of the United States.*)

These winds are of the föhn type, being heated by compression in their descent from the mountains, like the Sirocco of north Sicily. The northern part of the Great Valley experiences similar hot winds, which blow down from the plateau on the east of the Cascade Range. Their dry heat is very destructive to vegetation if they blow in late spring; they are sometimes known as ‘ Northers ’, but their characteristics are very different from those of the cold Northers of Texas.

‘ Apricots, cherries, almonds, walnuts, peaches, pears, plums. grapes, figs, and olives are grown most successfully (in California), and citrus fruits of all kinds flourish in the foothills. This is the only section of the United States in which raisin making is carried on.’ (*Ibid.*)

In British Columbia there is a similar contrast between the cool coast and the warm interior in summer. Vancouver Island has a July mean of about 60°, the temperature being very similar to that of the British Isles in summer as in winter ; at Kamloops the July mean is 70° ; thus the increase in temperature towards the interior is much less than in California.

The warmest part of Canada is the east of Alberta. Farther east, in spite of decreasing altitude, the temperature becomes lower ; Winnipeg is cooler than Medicine Hat in summer as in winter. The Great Lakes cool their neighbourhood considerably ; at Dubuque the July mean is 74° (absolute maximum 106°), at Milwaukee 70° (absolute maximum 100°).

The coast of Labrador is cool, and foggy in summer. The 50° isotherm for July dips south almost to Newfoundland, nearly all the Labrador coast and much of the interior having a mean below 50°, and in an average year the temperature never reaches 80°. A month rarely passes in which frost does not occur, even in summer; though the latitude of south Labrador is that of Liverpool, the summers are as cool as in the delta of the Mackenzie River. The inclement weather is due to the cold Labrador current which chills the inblowing winds, and causes much fog. The interior enjoys less inhospitable conditions.

The north coasts of the continent have similar summers to those of Labrador, the temperature being kept low by the numerous lakes and marshes, and the melting ice in the adjoining channels. Away from the coast the Mackenzie and Yukon basins have warm, if short, summers. At Dawson City, which has experienced a minimum of −69°, 89° was once recorded, giving an extreme range of 158°. The Yukon is much warmer in summer than the neighbourhood of Hudson Bay.

The isotherms bend northward between the Great Lakes and the Gulf of St. Lawrence. Montreal has a mean July temperature of 69°, a higher figure than is found on the coast of the Atlantic or on the shores of the Lakes, but considerably lower than in the same latitude between the Lakes and the Rockies.

In the centre and east of the United States temperature is very uniform in summer; the isotherms are far apart, in striking contrast to those of the west coastal region. The south-west of the States is warmest, the neighbourhood of the lakes and the coast of Maine coolest. In the Mississippi valley the temperature is kept down by the cloudy sky and damp air; the high plains on the east of the Rockies enjoy clearer skies, but the altitude prevents a very high mean temperature, the warm days being followed by cool nights. East of the Mississippi, sea influence is stronger and hence the temperature is lower. The following table shows the summer temperatures at typical stations:

	Altitude. Feet.	*Mean Temperature in July.*	*Highest Temperature ever recorded.*
Galveston	69	84	98
San Antonio	701	83	107
Denver	5,272	72	105
Omaha	1,103	76	106
Shreveport	249	83	110
St. Louis	568	79	107
Vicksburg	247	80	101
New Orleans	51	82	102
Key West	14	84	100
Columbia (S.C.)	351	81	106
New York	140	74	100
Chicago	824	72	103

The heat is much less than in the arid western States, but it is associated with moist air, especially on the shores of the Gulf, so that the climate is oppressive for white labourers. This is one reason for the employment of negro slaves in the southern States, with far-reaching social consequences.

The cold waves of winter have a summer parallel in the hot waves of the south and east of the States, which are spells of hot weather with very moist air, brought by the south and south-east winds which blow when an anticyclone is situated off the east coast, and a low-pressure system lies over the Mississippi valley. The moist heat is very enervating though the thermometer may not rise above 100°, and it causes many cases of heat stroke and prostration. The greater heat of the western plateau is much easier to bear since the air is dry and exhilarating.

The following table shows the July temperatures at typical stations on the west and east coasts of North America and Eurasia, the winter conditions at which have been already considered.

West Coast.	*Lat. ° N.*	*Mean July Temp.*	*East Coast.*	*Lat. ° N.*	*Mean July Temp.*
North America.					
Sitka	57·0	54	Nain	56·5	46
Victoria	48·5	60	St. John's (Newf'dl'd)	47·5	59
Eureka	41·0	55	New York	41·0	74
San Diego	32·5	67	Savanna	32·5	80
Eurasia.					
Portree	57·5	56	Aian	56·0	54
Brest	48·5	64	East coast of Siberia	48·5	63
Oporto	41·0	67	Vladivostok	43·0	66
Mogador	32·5	68	Shanghai	31·0	80

The slow change of temperature from north to south on the west coasts as compared with the east is noticeable. The south part of the west coast of America is remarkably cool owing to the California current (compare Eureka and New York). On the east coast we find remarkably low temperatures in the north, caused by the Labrador current. America is cooler than Eurasia everywhere on the west coast; the east coasts are very similar in the south, but Labrador is much cooler than east Siberia.

Almost everywhere in North America autumn is warmer than spring. Texas and the interior of British Columbia are exceptional in having April slightly warmer than October. That the coasts should have warmer autumns is not surprising; but it is noteworthy that even the plains in the far interior, such as Dakota, have the same characteristic, and differ in this respect from the steppes of Asia. The explanation doubtless lies in the easy access offered by North America to oceanic influences.

	Mean Temperature.		
	April.	*October.*	*Difference October–April.*
Victoria	48	50	2
Kamloops	50	48	—2
Medicine Hat	45	46	1
Kingston	42	48	6
St. John's (Newf'dl'd)	35	45	10

The range of temperature from the warmest to the coldest month is greatest in the north-west of Canada, where it exceeds 80°, least on the coasts, especially on the west coast. It is everywhere less than in corresponding regions of Eurasia. The Californian coast has a remarkably low range, less than 10°, a lower figure than is found even in the most equable parts of the west coasts of Europe.

Tornadoes. All the United States east of the Rockies is liable in summer to severe storms of wind, called Tornadoes. They are rapidly revolving whirls, with a diameter in most cases of only some 400 yards, and they travel in a more or less straight line along their path of destruction, with a speed of 20 to 40 miles an hour. They usually die out after travelling about 20 miles. They are secondary disturbances in the south or south-east sector of extensive low-pressure systems, and their fury and frequency in America are doubtless due to the ease with which on the open plains cool dry currents from the north encounter the hot moist air from the Gulf. Tornadoes are most frequent in the valleys of the Upper Mississippi and Missouri where, in the centre of the continent, the opposing winds probably have the greatest differences of heat and humidity (Fig. 105).

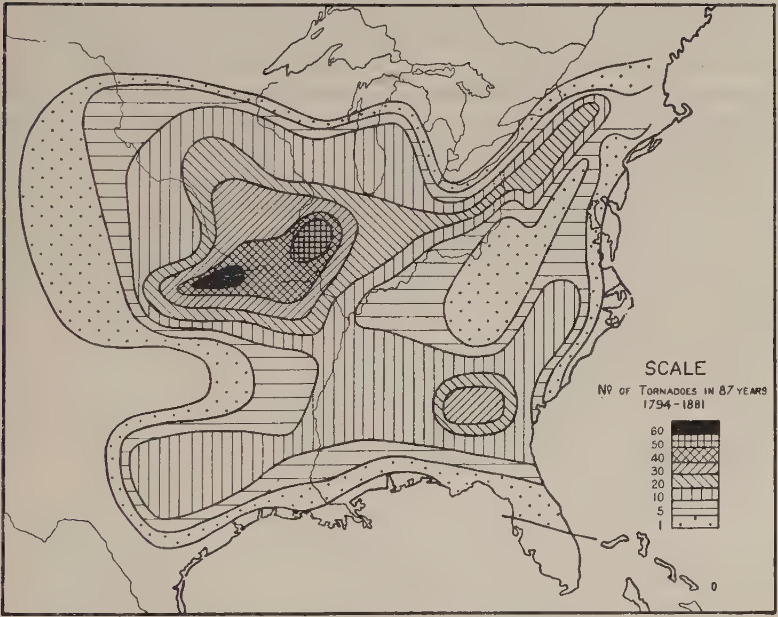


Fig. 105. Frequency of Tornadoes.

They are confined to the warmest months, and almost entirely to the warmest part of the day. The following description is given in the *Climatology of the United States* by an eye-witness of a tornado which passed over Sherman, Texas, in May 1896.

> 'When the cloud passed in front of me it seemed to be going at the speed of a galloping horse. The speed was not so great but that almost any one running to the east or to the west could have got out of the way. The cloud swelled out above the ground, but the top of it was higher than the sides. It seemed to be churning up all that it touched and throwing out the fragments at the top. At the same time as it moved along the mass had a rotary motion. It whirled round and round in a direction from right over to left. Only the outlines of the mass could be distinguished. It was impossible to see into it. Houses and other things went up as the cloud reached them, disappearing in the revolving interior. At the top and around the edges I could see things whirling and then falling as they got beyond the edges. The revolving velocity was so great that it set the adjacent air in motion, and the lighter things, such as leaves and twigs and bits of pine and particles of mud, circled far outside of the cloud and fell at considerable distances from the path of the cyclone.'

The hurricanes which sometimes work havoc on the coasts of the Gulf are referred to in the section on the West Indies (p. 338).

CHAPTER XXXV

RAINFALL

We shall first consider the yearly amount of rainfall, and afterwards the seasonal distribution (Figs. 106 and 107). The rainiest part of the continent is the Pacific littoral, where the westerlies, blowing from the warm ocean, meet the mountains on the coast, and the resulting ascent, together with the usual cyclonic activity of the westerlies, produces very copious condensation. The heaviest rainfall is in the neighbourhood of the international frontier, where it exceeds 100 inches per annum in many places. The highest record for the United States, 133 inches, is at Glenora, 575 feet above the sea, on the west face of the Coast Range in north Oregon. The rainfall is even greater in the west of Vancouver Island, and on parts of the coast of British Columbia.

South of Cape Mendocino it diminishes rapidly from 50 inches to 23 inches at San Francisco, and 10 inches at San Diego. It is to be noted that the east slopes of the Coast Ranges as well as the west receive a considerable rainfall, since they are the windward slopes when the wind is SE. in front of cyclones approaching the coast.

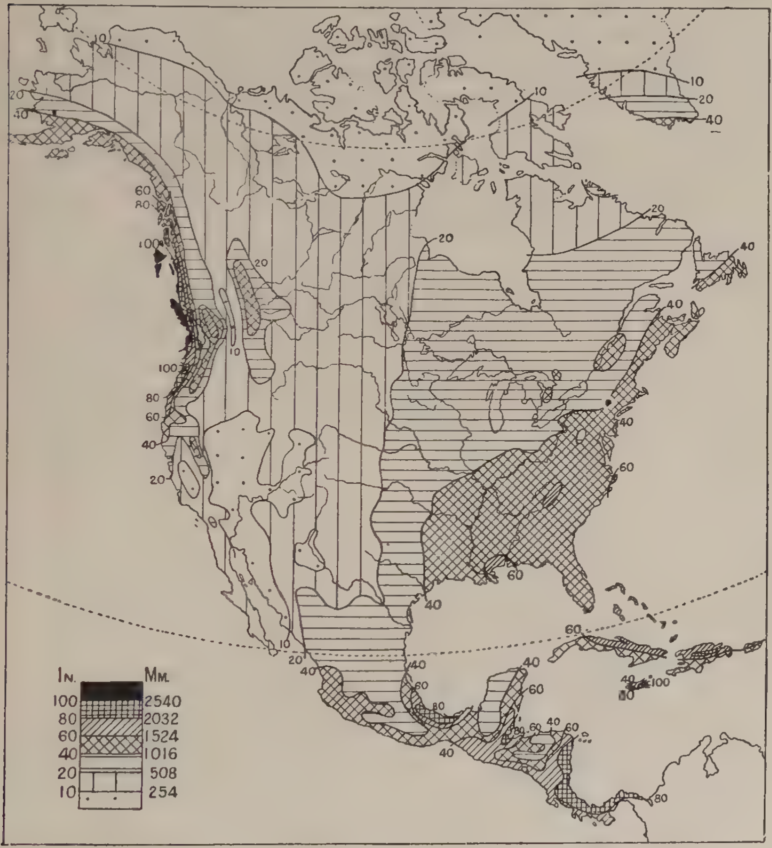


FIG. 106. Mean annual Rainfall.

The close relation between rainfall and relief is evident also in the great longitudinal depression, known in its various parts as the Strait of Georgia, Puget Sound, the Willamette Valley, and the Great Valley of California. The depression has from 30 to 50 inches in British Columbia, 30 to 40 inches in Washington and Oregon, 15 to 20 inches in the Sacramento Valley, less than 10 inches, and in places as little as 5 inches, in the valley of the San Joaquin. The rainfall is least in many parts not on the floor of the valley, but on the lower slopes of the eastern side.

The Cascade Range of British Columbia and the northern states, and the Sierra Nevada cause the rainfall to increase again, but the increase continues only up to about 4,000 feet, above which the rainfall decreases slowly (inversion of rainfall). The decrease is continued on the lee slopes; unlike what we have seen to occur on the east slopes of the Coast Ranges, south-east winds blowing into cyclones here give but little rain owing to the distance from the sea. The intermont plateaux of the west of the continent are very dry, since the double mountain barrier on the west deprives the westerlies of their moisture, and the Rocky Mountains on the east help, though in a much less degree, to intensify the aridity. As in all the west of the continent the rainfall of these plateaux is greatest in the north; the interior of Washington and Oregon and the west of Idaho receive 10 to 20 inches, but Nevada and the Colorado basin less than 10 inches, since the westerlies are less strong and the enclosing mountains in general higher. The driest tract is the lower Colorado basin, from which many annual means of 3 inches, 2 inches, and even 1 inch are reported. As in most deserts the rainfall is very variable in amount from year to year. Thus Yuma, Arizona, had less than 1 inch in 1899, but over 11 inches in 1905; the average is 3 inches, falling on 13 days. Fort Apache, Arizona, had 12 inches in 1903, 33 inches in 1905. Pinal Ranch, Arizona, 5,000 feet above the sea, had 12 inches in 1903, 58 inches in 1905. This arid region has very dry air and remarkably clear skies, the sunshine record of more than 3,250 hours per annum being the highest mean for the continent. The ranges which rise on the plateau have a somewhat heavier rainfall, the Wahsatch Range over 15 inches. The interior of British Columbia has probably less than 10 inches a year in many parts, but the amount is less variable from year to year than in the Colorado basin; moreover, since the air is cooler and less dry, there is less evaporation, and, therefore, more of the rainfall is available for agriculture.

The rainfall increases again on the Rocky Mountains, but surprisingly little considering their altitude. A small part of

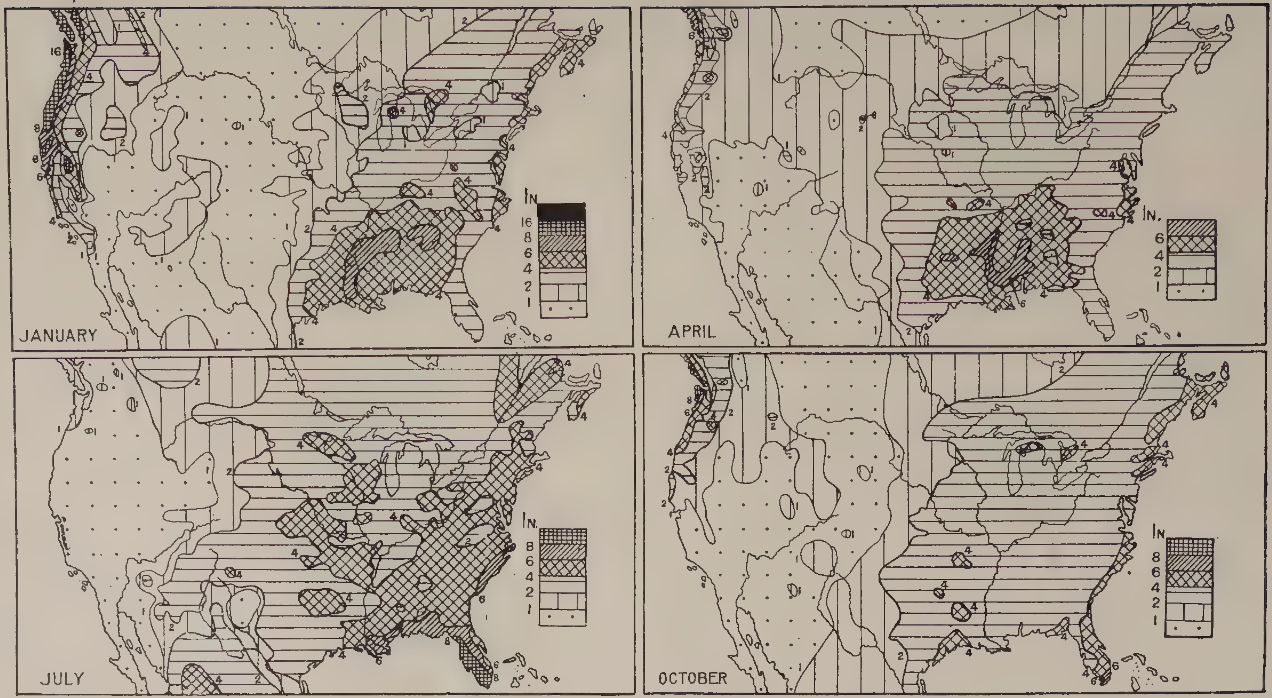

JANUARY
IN.
16
8
6
4
2
1
APRIL
IN.
6
4
2
1
JULY
IN.
8
6
4
2
1
OCTOBER
IN.
8
6
4
2
1

FIG. 107. Mean monthly Rainfall. (Harrington and Herbertson; *Atlas of Meteorology.*)

Kootenay, B.C., has over 50 inches, but in the United States there is, in most of the Rocky Mountains, not much more than 25 inches, and in many parts even less. The heaviest rainfall seems to be on the top of the mountains, not on the lower slopes as in the Sierra Nevada. Pike's Peak, 14,111 feet, has 29 inches. The western face of the Rockies is the rainier in most parts, which shows that they are within the influence of the westerlies.

East of the Rockies the rainfall is less in the steppe lands of the great plains, but the great plains have considerably more rain than the arid plateaux; the rainfall is probably least in south Saskatchewan, where it is somewhat under 10 inches; in the northern forest belt there is probably more than 15 inches. In the United States the strip of country between the foot of the Rockies and 100° W. long. has a mean rainfall between 12 and 20 inches. It is liable to vary very much from year to year, and is so low in bad years that agriculture cannot be safely carried on.

From the 100th Meridian the rainfall increases steadily towards the east and south. An irregularity is caused by the Appalachians, the southern end of which being lofty, and within range of the moisture-bearing winds from both the Gulf and the Atlantic, has more than 70 inches, the highest total in the United States if we exclude the Pacific coast. On the coast of the Gulf of Mexico the rainfall exceeds 60 inches between New Orleans and Mobile; the heavy rainfall here is largely caused by the hurricanes of the West Indies region in late summer. The Great Lakes cause an increase of rainfall in their neighbourhood.

In most of the east of America as well as in the west there is considerable precipitation in the winter months; on part of the east coast it even exceeds that of summer, a peculiarity which will be referred to again later. The winter temperature is so low that a large part of the precipitation north of lat. 37° N. is in the form of snow; America is the snowiest of the continents. On the Pacific coast and the coast range it is too warm for much snow to fall, but on all the other ranges of the western mountains there is a heavy snowfall of at least 16 feet per annum, and in many parts much more. Over large areas in the Sierra Nevada and the Cascades the mean exceeds 40 feet a year. On the plateaux there is much less, but the total rises again in the Rockies, which have over 20 feet in many parts; the melting of the masses of snow provides abundant water for irrigating the lower lands in summer. In the south of Saskatchewan in the heart of the continent there is a mean annual snowfall of 2 to 4 feet. The amount increases rapidly towards the east, and probably exceeds 4 feet everywhere east of Winnipeg; on the east shores of the Lakes the snow is especially heavy, as much as 17 feet falling in some places. The neighbourhood of the Gulf of St. Lawrence also has much snow, over 8 feet in most parts. East Canada is the snowiest region of America outside the mountains, and the heavy winter snowfall is one of the most striking features of the climate; at Montreal it snows on an average on 18 days in January and rains on only 4 days.

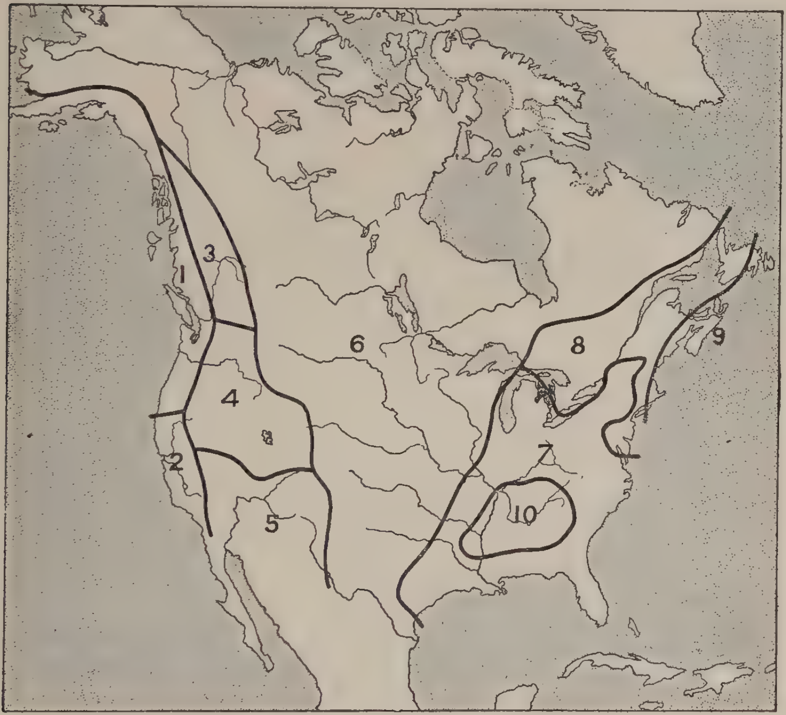


FIG. 108. Rainfall régimes.

The seasonal distribution of rainfall. The main types of rainfall distribution are mapped in Fig. 108. The abundant and excellent rainfall records available from the United States enable the bounding lines to be drawn with confidence, and help us to make the best use of the scanty records from most of Canada. The characteristics of the types are as follows.

1. The Pacific type (Olympia, Fig. 109) covers the coastal strip as far as, and including, the Cascade Range. There is a pronounced winter maximum, December being the rainiest month, July and August the driest. The same type extends north to Alaska, but north of Vancouver Island the maximum comes rather earlier, at Port Simpson in November (Fig. 110), at Sitka in October. We are reminded of the coasts of North-west Europe, but the much drier summers are characteristic; they are connected with the great extension of the North Pacific anticyclone at that season. The rain is cyclonic, and in most of the region orographic also, and it is very abundant.

2. The California type (San Francisco and San Diego, Fig. 111), like the Pacific, belongs essentially to the coast, but extends over the great valley of California and the Sierra Nevada. The rain falls in winter, as farther north, but the rainless summer of two to four months is distinctive. The prevailing summer winds at San Francisco are SW. and W., which we might have expected to be rainy; but they are mostly merely sea breezes, and having crossed the cold current bring no rain. This type corresponds to that of the Mediterranean lands in the Old World, but the autumn and spring maxima of rainfall which characterize a large part of that area are not found in California, where the rainfall increases steadily to its December maximum, and then decreases steadily to the rainless summer. In amount the rainfall varies from moderate to scanty.

3. The interior of British Columbia. We have just studied the oceanic type with most rain in winter which prevails on the west of the Cascade Range. East of the Rockies we shall find almost exactly the opposite distribution, little rain in winter, and a maximum in early summer. Between the two regions there is a transition type, 3, with nearly equal rainfall in the winter and summer half years. Late summer and autumn are the rainiest seasons, spring the driest; the rains of autumn are doubtless related to those of the coast, which has its heaviest fall at that time. Good records from this region are as yet very few, and it may be necessary to modify the above statements in the light of further data.

4. (Boisé and Salt Lake City, Fig. 112.) South of the international frontier the Pacific coast influence is stronger, and considerably more rain falls in the winter than in the summer

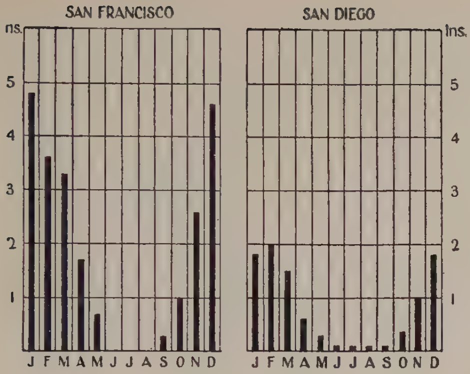


Fig. 111.

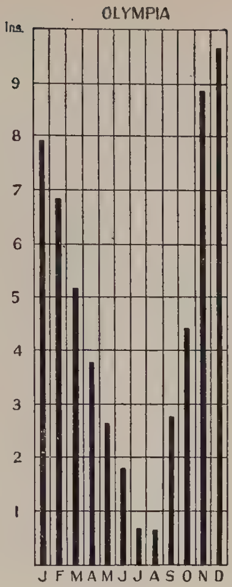


Fig. 109.

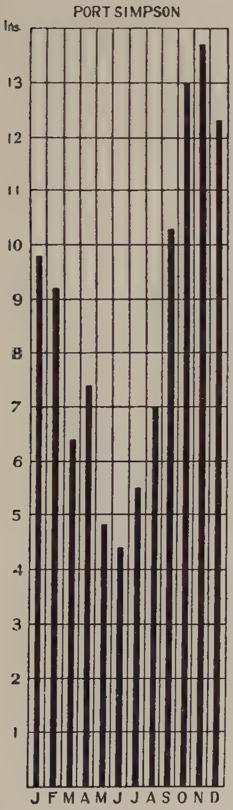


Fig. 110.

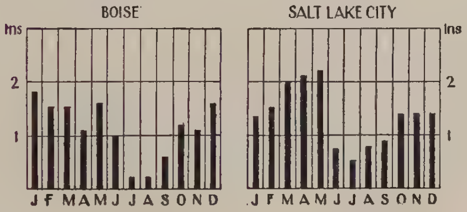


Fig. 112.

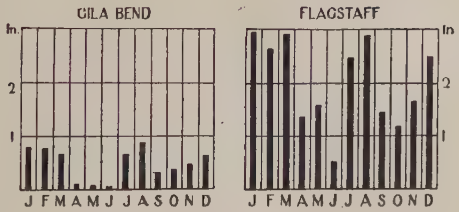


Fig. 113.

half-year. December and January are in most parts the rainiest months, and there is a secondary maximum, clearly marked everywhere in spring and early summer (compare 3), which is the rainiest part of the year in the plains to the east. Late summer is dry. We may designate this the Snake River type ; it extends as far east as the western foot of the Rockies.

5. The Arizona type (Gila Bend and Flagstaff, Fig. 113) includes the driest tracts of the continent. The rainfall curve shows two influences at work, that of the Pacific coast, which produces a maximum in winter, and that of the intense local heating in late summer, which causes convectional overturnings and showers of rain in July and August, especially on the mountains. June is almost rainless.

6. This type prevails with great uniformity over an enormous area, from the extreme south of the United States to the barren lands of north Canada. We may name it the Plains type (Omaha, Bismarck, and Winnipeg, Fig. 114). The rainfall shows a strong periodicity. The early summer months are the rainiest, with a pronounced maximum in June. Winter is a dry season, but no month is rainless, though December and January have less than half an inch each, all of it in the form of snow, in the central parts of the region. The heavy rainfall of the early summer is due to the rapid heating of the ground, and the air resting on it, while the higher layers of the atmosphere are still cold, so that the convectional overturnings cause heavy showers.

The neighbourhood of Lake Superior is included in this region, but the lake modifies the rainfall régime somewhat. The maximum is in June as elsewhere, but the fall in the curve towards autumn is checked.

In the Tundra of the north of the continent there is a somewhat similar modification ; the summer maximum is delayed till July and autumn is rainier than spring (Fort Chipewyan, Fig. 115). The same modification appears to be general in Labrador. Its cause is doubtless the proximity of the sea, and the fact that the ground is frozen hard in winter, so that the spring rise in temperature is delayed. We cannot draw the boundary of this modified type in view of the scantiness of the records from north Canada.

7. (Galveston and Raleigh, Fig. 116.) This Gulf type is distinguished by its late summer maximum, the rainfall

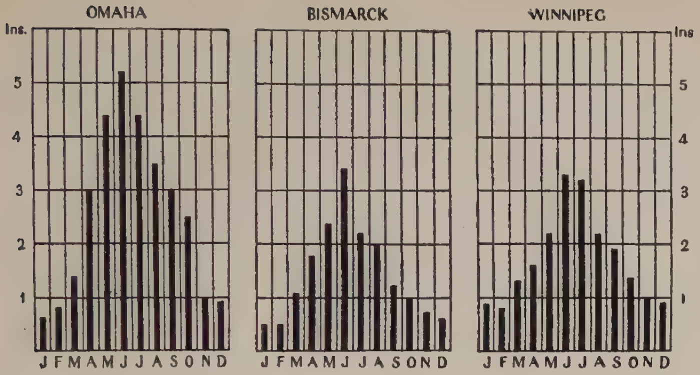


FIG. 114.

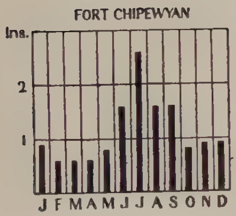


FIG. 115.

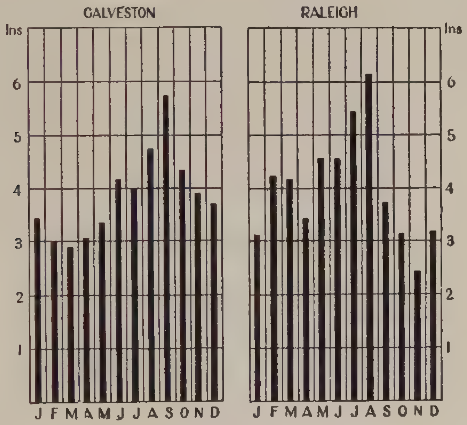


FIG. 116.

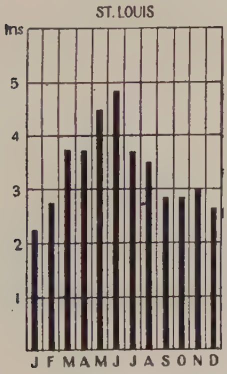


FIG. 117.

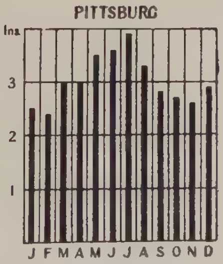


FIG. 118.

increasing very noticeably in August and September; winter is much rainier than in the Plains, and there is considerable rain in all seasons. There are several cyclone tracks, much frequented all the year, in or near the region with this régime, notably those of the Gulf of Mexico, off the Atlantic coast, and up the Mississippi valley, and owing to the proximity of the sea the cyclones cause heavy rain. The late summer maximum is largely due to the extremely heavy downpours associated with hurricanes. These storms originate east of the West Indies and often travel into the Gulf, whence they recurve towards the north-east (p. 338), causing terrible havoc on any land they touch.

The true Gulf type is found on the coast of the South Atlantic States as well as near the Gulf of Mexico, but it does not extend very far from the coast. In eastern Missouri, part of Illinois, Indiana, Michigan, and Ohio, there is an approximation to the plains type in that the maximum is in early summer (St. Louis, Fig. 117), but the abundant rain in winter shows that this region must be classed with the Gulf rather than with the Plains. Still farther towards the north-east, in Pennsylvania and western New York, we trace the influence of the Great Lakes, and perhaps of the Atlantic Ocean, in the retardation of the maximum which occurs here in late summer, so that the régime again approaches that of the shores of the Gulf (Pittsburg, Fig. 118); but there is less difference between the rainfalls of the wettest and driest months, and this feature shows the transition to the St. Lawrence type.

Types 8 and 9 present the most anomalous feature in the meteorology of North America.

8. The St. Lawrence type (Toronto, Montreal, and New York, Fig. 119). The chief feature is the remarkable uniformity of the rainfall throughout the year. At most stations there is a slight maximum in late summer, and a slight minimum in spring, and the summer half year has more rain than the winter half.

9. (Parry Sound, St. John's, Halifax, Fig. 120.) On the eastern shore of Lake Huron there is more rain in the winter half-year, and the monthly maximum is in January. The same régime is found in a large area along the east coast of the continent and on

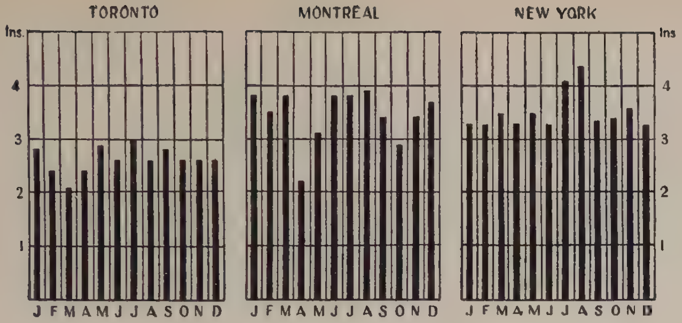


Fig. 119.

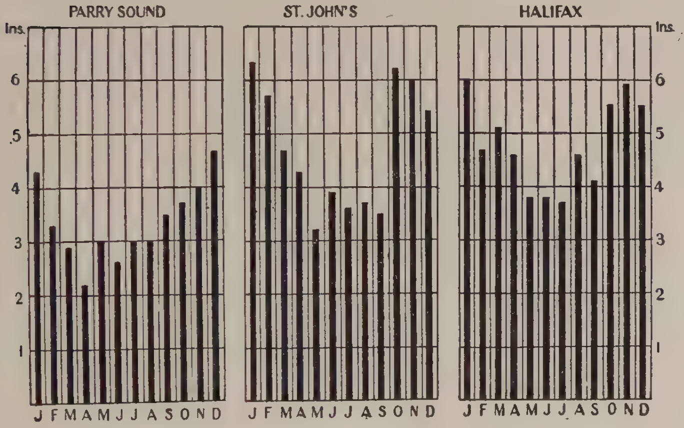


Fig. 120.

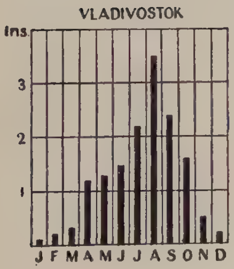


Fig. 121.

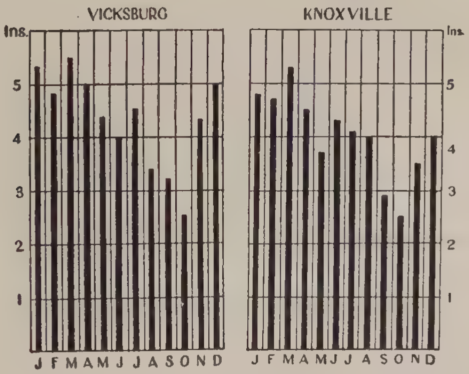


Fig. 122.

the islands from Newfoundland to Long Island. We may designate it the Nova Scotia type.

Here, then, is the very striking peculiarity of a pronounced winter maximum of rainfall on the east coast of a continent in the temperate zone. Vladivostok (Fig. 121), situated in the same latitude on the east coast of Asia, shows the régime which may be considered the normal one, with a maximum in summer and a minimum in winter. The abundant winter precipitation of the St. Lawrence basin is no doubt due primarily to the presence of the Great Lakes, the Gulf of St. Lawrence running far into the land, and the ocean. The moisture and warmth over these bodies of water cause cyclones to show a pronounced tendency to make for the Lakes, and pass over them and the Gulf of St. Lawrence to the sea. In other words the most frequented cyclone tracks converge in the neighbourhood of the Lakes, and hence there is a probability that a cyclone which appears anywhere in the continent will leave it *via* the St. Lawrence. As cyclones are specially numerous and vigorous in winter the precipitation is abundant there at that season, in spite of the low temperature and the resulting low vapour-capacity of the air.

It is interesting to notice how the St. Lawrence type of rainfall régime spreads north and south near the coast, especially southward, where it extends as far as Washington.

10. The Southern Appalachian type is anomalous like 9 in having more rain in the winter than in the summer half-year, but while 9 has a wet autumn and a dry spring the Southern Appalachian region has least rain in autumn, and the early spring months are in some places the rainiest of the whole year; the rainfall curve sinks in May and rises again to a secondary maximum in summer (Vicksburg and Knoxville, Fig. 122).

On the whole this type has affinities with the Gulf type, from which it differs chiefly in having no pronounced summer maximum, and, as a result, more rain in the winter than in the summer half-year.

MEAN TEMPERATURE (°F.)

CANADA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Fort Chipewyan .	699	*–13·2*	–9·2	3·9	27·9	45·3	55·9	**61·9**	57·7	44·8	32·5	14·2	0·5	27·8	75·1
Dawson City .	1,200	*–23·9*	–13·5	3·0	28·2	47·5	57·9	**59·7**	54·8	41·9	27·1	–0·7	–9·8	24·2	83·6
Sitka . .	62	*30·2*	31·8	34·5	39·7	45·9	51·3	54·5	**54·7**	50·5	43·9	37·4	32·9	42·3	24·5
Port Simpson (B.C.)	26	*34·0*	34·8	37·6	41·6	48·3	52·8	56·0	**56·7**	52·2	47·1	39·7	36·9	44·8	22·7
Victoria . .	85	*39·2*	40·3	43·1	47·7	53·0	57·1	**60·3**	60·0	55·6	50·4	44·5	41·5	49·4	21·1
Kamloops . .	1,193	*22·4*	26·5	37·6	49·7	57·5	64·6	**69·6**	68·1	58·4	47·8	35·8	28·8	47·2	47·2
Calgary . .	3,389	*11·3*	14·5	25·1	39·9	48·9	55·9	**60·7**	58·7	50·5	41·9	26·4	26·5	37·8	49·4
Winnipeg . .	1,492	*–3·5*	–0·5	15·2	38·7	51·5	62·6	**66·2**	62·7	54·1	41·6	22·0	7·2	34·8	69·7
Port Arthur .	644	*7·0*	7·4	19·1	35·1	45·9	56·4	**62·2**	59·9	52·8	41·6	26·9	14·4	35·7	55·2
Toronto . .	350	22·9	*21·1*	30·2	43·1	53·6	64·6	**69·1**	67·2	60·8	48·3	37·4	27·7	45·5	48·0
Ottawa . .	294	*12·0*	13·5	25·7	42·7	55·8	65·1	**69·7**	66·7	58·9	46·6	32·3	16·9	43·0	57·7
Montreal . .	187	*13·2*	14·6	25·9	41·7	55·0	65·1	**69·0**	66·3	58·8	46·1	33·1	19·1	42·3	55·8
Quebec . .	296	*10·1*	11·7	23·0	37·1	51·5	61·2	**66·3**	63·0	55·4	43·0	29·8	15·4	38·7	56·2
Halifax . .	88	24·1	*23·9*	31·5	40·1	49·3	57·6	64·6	**64·6**	58·8	48·8	39·7	29·3	44·3	40·7
St. John's (Newfoundland) .	125	24·2	*23·3*	28·5	35·4	42·7	49·7	58·9	**59·3**	53·7	45·4	37·6	28·9	40·1	36·0
Nain . . .	13	*–7·1*	–3·1	5·2	18·9	30·2	39·9	46·2	**46·9**	40·6	31·3	19·8	2·8	22·6	54·0
Hebron . .	49	*–5·7*	–5·1	5·8	18·3	31·5	40·0	47·1	**48·1**	40·9	31·2	19·8	4·2	23·0	53·8

UNITED STATES OF AMERICA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Albany . .	97	*23·4*	24·4	33·3	46·7	59·2	68·4	**72·3**	70·5	62·5	50·2	39·1	28·0	48·2	48·9
Albuquerque .	5,200	*33·8*	39·3	47·2	55·7	64·7	73·4	**77·1**	75·3	67·8	56·6	43·3	34·4	55·7	44·3
Austin . .	6,594	*26·8*	30·7	35·1	43·4	51·1	60·4	**69·1**	68·3	59·0	47·9	38·7	30·9	46·8	42·3
Bismarck . .	1,674	*7·0*	9·6	22·7	42·9	54·3	63·4	**69·3**	67·6	57·7	44·7	27·3	15·4	40·0	62·3
Boisé City . .	2,770	*29·3*	33·8	42·2	50·1	57·6	66·0	**72·8**	71·8	61·9	50·3	39·6	32·2	50·6	43·5
Boston . .	124	*27·0*	28·0	35·0	45·3	56·6	65·8	**71·3**	68·9	62·7	52·3	41·2	31·6	48·8	44·3
Charleston . .	48	*49·3*	51·7	57·2	63·8	72·4	78·5	**81·3**	80·3	76·2	67·1	58·1	51·3	65·6	32·0
Chicago . .	824	*24·0*	25·5	34·9	46·2	56·6	66·5	**72·3**	71·2	64·8	53·2	39·2	29·3	48·7	48·3

MEAN TEMPERATURE (°F.), *continued.*

UNITED STATES OF AMERICA (*continued*)

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Cleveland	571	*27·1*	27·9	34·7	46·7	58·3	67·7	**71·9**	69·6	63·4	52·1	40·4	31·3	49·3	44·8
Denver	5,272	*29·6*	32·1	39·0	47·4	56·4	66·1	**71·8**	70·7	62·4	49·6	39·1	32·5	49·7	42·2
Duluth	1,133	*10·4*	13·3	24·0	38·4	48·0	57·7	**65·7**	64·6	56·6	45·2	29·4	16·8	39·1	55·3
Eureka	64	46·9	*46·8*	48·0	49·5	52·1	54·6	55·3	**55·8**	54·9	53·1	51·0	48·0	51·3	9·0
Galveston	69	*53·6*	55·7	62·9	69·5	75·8	81·6	**83·6**	83·3	79·8	72·5	63·0	56·5	69·8	30·0
Harrisburg	361	*28·7*	29·9	37·8	50·7	61·7	70·3	**74·5**	72·1	64·9	54·0	41·7	32·8	51·6	45·8
Helena	4,110	*20·0*	22·7	31·7	44·0	51·8	59·1	**66·9**	66·2	56·2	45·8	32·3	26·3	43·6	46·9
Indianapolis	822	*28·4*	30·4	40·1	52·4	63·3	72·3	**76·1**	73·9	66·9	55·1	41·4	32·5	52·7	47·7
Miami	5	*65·7*	67·8	72·3	74·0	78·5	80·9	82·2	**82·4**	81·4	77·4	73·2	68·7	75·4	16·7
Montgomery	240	*47·8*	51·0	58·2	65·2	73·4	79·9	**82·1**	80·8	76·3	65·7	55·9	49·2	65·5	34·3
Nashville	573	*38·0*	41·1	49·2	59·1	68·8	76·3	**79·4**	77·8	71·5	60·3	48·7	41·1	59·3	41·4
New Orleans	51	*53·9*	56·8	63·1	68·7	74·6	80·0	**81·5**	81·3	77·6	68·8	61·1	54·8	68·4	27·6
New York	coast	*30·3*	30·6	37·7	48·5	59·4	69·0	**74·5**	72·8	65·9	55·2	44·1	34·2	51·8	44·2
Olympia	,,	*38·7*	40·3	44·3	48·9	54·6	59·2	**63·0**	62·7	56·9	50·8	44·4	41·1	50·4	24·3
Omaha	1,103	*20·5*	23·7	36·0	50·5	62·5	71·6	**76·5**	74·4	65·8	54·2	37·7	27·1	50·0	56·0
Oswego	335	*23·7*	24·1	30·6	42·5	53·6	63·1	**69·1**	67·8	61·3	49·8	38·6	28·4	46·0	45·4
Pike's Peak	14,111	*2·4*	3·7	7·9	12·9	22·6	32·8	**40·0**	38·6	32·2	21·6	11·2	6·2	19·3	37·6
Pine Bluff (Ark.)	215	*42·5*	45·0	54·5	63·6	72·0	79·1	**82·4**	81·4	75·7	63·3	52·8	45·3	63·1	39·9
Pittsburg	842	*30·7*	31·8	39·5	51·0	62·6	71·1	**74·6**	72·5	66·1	54·9	42·9	34·7	52·7	43·9
Portland	99	*22·0*	23·8	32·0	43·0	43·5	62·6	**68·0**	66·0	59·6	49·1	37·6	27·1	45·4	56·0
Raleigh	390	*40·4*	43·3	50·4	59·0	68·1	75·1	**78·5**	76·8	70·6	60·5	50·2	42·7	59·9	38·1
Sacramento	71	*45·6*	50·2	54·2	58·0	62·9	68·9	**72·5**	72·1	69·1	62·2	53·4	46·3	59·6	26·9
Salem	120	*40·7*	43·1	45·8	50·6	56·2	61·2	**66·4**	66·3	60·7	53·6	47·0	42·2	52·8	25·7
Salt Lake City	4,366	*29·0*	33·4	41·3	49·8	57·4	66·9	**75·5**	74·5	64·4	52·3	40·6	32·1	51·4	46·5
San Antonio	701	*52·7*	54·7	63·0	69·4	75·2	81·0	83·2	**83·3**	78·6	70·3	60·8	54·3	68·9	30·6
San Diego	93	*54·0*	54·6	56·2	58·2	60·8	63·8	66·9	**68·7**	66·9	63·0	59·0	55·7	60·6	14·7
San Francisco	207	*49·5*	51·3	52·7	53·7	55·5	57·0	57·3	58·0	**59·3**	58·4	55·5	50·9	54·9	9·8
St. Louis	568	*31·0*	33·5	43·5	56·1	66·5	75·1	**79·1**	77·2	70·0	58·4	43·4	35·5	55·8	48·1
St. Paul	848	*11·9*	15·4	28·2	45·8	57·7	67·2	**72·0**	69·7	60·5	48·4	31·0	18·8	43·9	57·1
Vicksburg	247	*47·0*	50·9	58·2	65·2	72·9	78·5	**80·4**	79·6	74·8	65·3	55·9	49·4	64·8	33·4
Washington	75	*32·9*	34·5	42·2	53·1	64·2	72·7	**76·8**	74·5	68·1	56·6	45·0	36·1	54·7	43·9
Yuma	141	*54·7*	59·2	64·5	70·1	76·8	84·7	**90·9**	90·1	83·9	72·4	61·0	55·7	72·1	36·2

RAINFALL (inches)

CANADA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Fort Chipewyan	699	0·9	0·6	*0·6*	0·6	0·8	1·6	**2·6**	1·6	1·6	0·8	0·9	0·9	13·5
Dawson City	1,200	1·0	0·7	*0·6*	0·7	1·0	1·1	1·8	1·6	**1·9**	1·3	1·2	1·1	14·0
Sitka	10	7·1	6·8	5·6	5·4	4·3	*3·5*	4·0	7·1	9·7	**11·7**	8·8	7·4	81·4
Victoria	85	4·5	3·5	2·5	1·7	1·3	0·9	*0·4*	0·6	2·0	2·5	**6·5**	5·9	32·5
Kamloops	1,193	0·9	0·8	*0·3*	0·4	0·9	1·2	**1·3**	1·0	0·9	*0·6*	1·0	**1·5**	11·0
Calgary	3,389	*0·5*	0·6	0·7	0·7	2·4	**3·2**	2·6	2·6	1·2	0·6	0·7	0·5	16·4
Qu'Appelle	2,115	*0·7*	0·8	1·0	1·1	2·7	**3·7**	2·8	2·0	1·4	1·0	1·0	0·7	19·0
Winnipeg	1,492	0·8	*0·7*	1·2	1·5	2·1	3·0	**3·2**	2·2	2·1	1·4	1·0	0·9	20·2
Port Arthur	644	0·8	*0·6*	0·9	1·6	2·1	3·0	**3·7**	3·0	3·1	2·4	1·3	0·8	23·3
Toronto	350	2·8	2·4	*2·1*	2·4	2·9	2·6	**3·0**	2·6	2·8	2·6	2·6	2·6	31·4
Ottawa	294	3·0	2·6	2·6	*1·9*	2·7	3·5	**4·0**	2·1	2·6	2·3	2·5	2·7	32·5
Quebec	296	3·4	3·3	3·3	*2·1*	3·2	4·1	**4·3**	4·0	3·8	3·1	3·0	3·1	40·7
Halifax	88	**6·0**	4·7	5·1	4·6	3·8	3·8	*3·7*	4·6	4·1	5·5	5·9	5·5	57·3
St. John's (Newfoundland)	125	**6·3**	5·7	4·7	4·3	*3·2*	3·9	3·6	3·7	3·5	6·2	6·0	5·4	56·5
Ramah	16	*0·8*	1·0	2·5	4·3	1·1	2·4	3·5	1·7	2·0	4·1	**5·4**	4·2	33·0

UNITED STATES OF AMERICA

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Albany	97	2·6	*2·5*	2·7	2·7	3·5	4·0	**4·1**	3·8	3·4	3·4	3·0	2·7	38·4
Albuquerque	5,200	0·4	*0·2*	0·2	0·5	0·4	0·8	1·2	**1·3**	0·9	0·7	0·5	0·4	7·5
Austin	6,594	1·2	1·3	1·5	1·5	**1·6**	0·6	*0·4*	0·6	0·5	0·6	0·7	1·2	11·7
Bismarck	1,674	*0·5*	0·5	1·1	1·8	2·4	**3·4**	2·2	2·0	1·2	1·0	0·7	0·6	17·4
Boisé City	2,770	**1·9**	1·5	1·5	1·1	1·5	1·0	0·2	*0·2*	0·5	1·2	1·1	1·6	13·3
Boston	124	3·7	3·5	4·1	3·8	3·7	*3·1*	3·5	**4·2**	3·4	3·7	4·1	3·8	44·6
Charleston	48	3·1	3·1	3·3	*2·4*	3·4	5·3	6·2	**6·7**	5·2	3·9	2·7	3·3	48·6
Chicago	824	*2·1*	2·3	2·6	2·7	3·6	3·5	**3·6**	3·0	3·1	2·4	2·5	2·1	33·5
Cleveland	571	2·5	2·6	3·0	2·7	3·8	**3·9**	3·8	3·1	3·8	3·0	3·2	2·7	38·1
Denver	5,272	*0·5*	0·5	1·0	2·1	**2·6**	1·5	1·6	1·3	0·9	1·0	0·5	0·6	14·1
Duluth	1,133	*1·0*	1·0	1·5	2·1	3·4	**4·4**	3·9	3·5	3·7	2·7	1·5	1·2	29·9

RAINFALL (inches), *continued*

UNITED STATES OF AMERICA (*continued*)

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Eureka	64	**7·9**	7·5	6·9	3·6	2·5	0·9	*0·1*	0·2	1·1	2·8	5·8	6·9	46·2
Galveston	69	3·4	3·0	*2·9*	3·1	3·4	4·2	4·0	4·7	**5·7**	4·3	3·9	3·7	46·3
Harrisburg	361	2·7	2·8	3·2	2·4	3·7	3·4	**3·9**	3·9	2·9	3·0	*2·3*	2·8	37·0
Helena	4,110	1·0	0·7	0·8	1·1	2·1	**2·3**	1·1	*0·7*	1·1	0·8	0·8	0·8	13·3
Indianapolis	822	3·0	3·1	4·0	3·4	4·0	**4·2**	4·1	3·2	3·0	*2·7*	3·5	3·0	41·2
Miami	5	3·3	2·5	2·8	3·1	5·9	7·9	7 2	7·3	**9·9**	9·2	2·4	*2·2*	63·7
Montgomery	240	5·1	5·5	**6·4**	4·3	3·8	4·2	4·7	4·2	2·9	*2·4*	3·1	4·5	51·1
Nashville	573	4·6	4·5	**5·2**	4·4	3·6	4·2	4·2	3·3	3·8	*2·3*	3·8	3·8	47·7
New Orleans	51	4·5	4·3	4·6	4·5	4·1	5·4	**6·5**	5·7	4·5	*3·2*	3·8	4·5	55·6
New York	coast	*3·3*	3·3	3·5	3·3	3·5	3·4	4·1	**4·4**	3·4	3·4	3·6	3·3	42·5
Olympia	,,	7·9	6·8	5·2	3·8	2·6	1·8	*0·7*	0·7	2·8	4·4	8·9	**9·7**	55·3
Omaha	1,103	*0·6*	0·8	1·4	3·0	4·4	**5·2**	4·4	3·4	3·0	2·5	1·0	0·9	30·4
Oswego	335	3·0	2·6	2·9	*2·5*	3·0	3·3	3·3	2·7	2·9	3·6	3·4	**3·7**	36·9
Pike's Peak	14,111	1·6	1·5	2·0	3·5	3·8	1·6	**4·2**	3·8	1·7	*1·4*	1·9	2·6	29·6
Pine Bluff (Ark.)	215	**5·9**	3·9	5·6	4·6	5·2	4·0	3·9	2·7	3·7	*2·0*	4·8	4·9	51·2
Pittsburg	842	2·5	*2·4*	3·0	3·0	3·5	3·6	**3·9**	3·3	2·8	2·7	2·6	2·9	36·2
Portland	99	3·8	3·4	**3·9**	*3·2*	3·6	3·3	3·5	3·5	3·3	3·7	3·7	3·8	42·7
Raleigh	390	3·1	4·2	4·2	3·4	4·6	4·6	5·4	**6·1**	3·7	3·1	*2·4*	3·2	48·0
Sacramento	71	3·8	2·9	3·0	1·6	0·8	0·1	*0*	0	0·2	0·9	2·1	**4·0**	19·4
Salem	120	5·8	5·3	4·7	2·8	2·2	1·3	*0·4*	0·4	1·6	3·1	5·6	**6·2**	39·6
Salt Lake City	4,366	1·3	1·5	2·0	2·1	**2·2**	0·8	*0·5*	0·8	0·9	1·4	1·4	1·4	16·3
San Antonio	701	*1·4*	1·6	1·8	2·7	3·2	2·7	2·5	2·6	**3·5**	2·0	2·2	1·8	28·0
San Diego	93	1·8	**2·0**	1·5	0·6	0·3	0·1	*0·1*	0·1	0·1	0·3	0·9	1·8	9·6
San Francisco	207	**4·8**	3·6	3·3	1·7	0·7	0	*0*	0	0·3	1·0	2·6	4·7	22·7
St. Louis	568	*2·3*	2·6	3·6	3·6	4·5	**4·8**	3·7	3·5	3·0	2·8	3·0	2·6	40·0
St. Paul	848	0·9	*0·8*	1·4	2·4	3·4	**4·1**	3·5	3·5	3·4	2·0	1·4	1·0	27·8
Vicksburg	247	5·2	4·8	**5·5**	5·0	4·3	4·0	4·6	3·4	3·3	*2·6*	4·3	5·0	52·0
Washington	75	3·1	3·1	3·5	3·3	3·7	3·7	**4·3**	4·1	3·3	3·1	*2·6*	3·0	40·8
Yuma	141	0·4	**0·5**	0·4	0·1	*0*	0	0·1	0·5	0·2	0·2	0·3	0·4	3·1

PART VI

SOUTH AMERICA, ETC.

CHAPTER XXXVI

GENERAL FEATURES

South America is the only one of the three southern continents which projects far into temperate latitudes. Unlike the land masses of the northern hemisphere it tapers poleward, with the result that we do not find that continental variety of temperate climate, with its great extremes of temperature, which is characteristic of the northern hemisphere. There is nowhere in South America any very great range of temperature from summer to winter. It is greatest in the north-west of the Argentine Republic, but even here it is less than 30°. Farther south the diminishing breadth of the continent more than neutralizes the increase in range which the higher latitude tends to produce. The continent is widest in the neighbourhood of the Equator, and the typical equatorial climate is found over vast areas. But the lofty ranges and plateaux of the Andes extend throughout the length of the continent, and their highest parts have a perpetual arctic climate even on the Equator; as South America has the widest expanse of true equatorial climate of all the continents, so also it may claim to have the greatest area in equatorial latitudes which enjoys a temperate or even an arctic climate. The Andes not only modify their own climate by their height, but also form a most important meteorological barrier, and thus affect the climate of the lands on either side.

Temperature (Fig. 124). The inter-tropical parts of South America are considerably cooler, due allowance being made for elevation, than the corresponding parts of Africa and Australia, owing to the greater cloudiness, heavier rainfall, and denser forests of the former. In January the hottest area is the south of Brazil and the north of the Argentine Republic; in July, Venezuela and

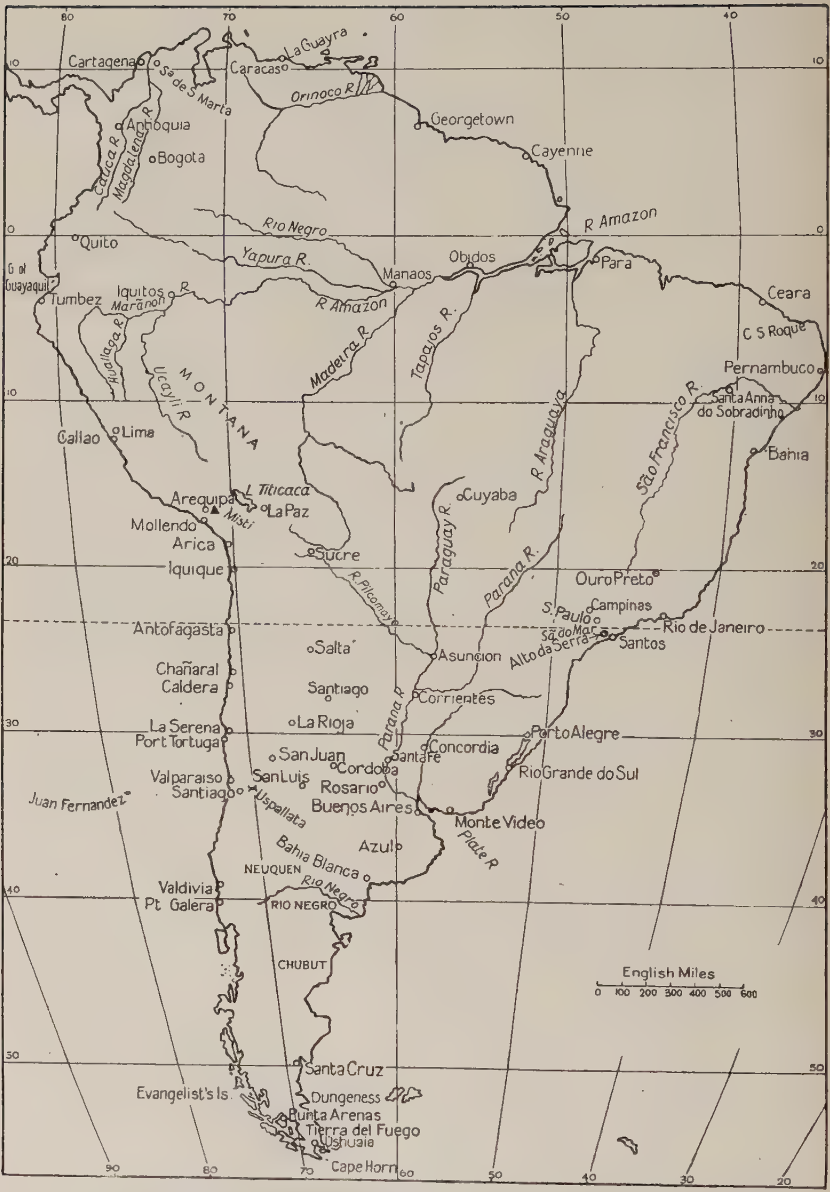

80
70
60
50
40
10
La Guayra
Cartagena
Caracas
Sa de S Marta
Orinoco R
Georgetown
Antioquia
Magdalena R
Cauca R
Bogota
Cayenne
Rio Negro
R Amazon
0
Quito
Yapura R.
Obidos
Manaos
Para
G of Guayaquil
Tumbez
Iquitos
Marañon R
R Amazon
Ceara
Tapajos R.
C S Roque
Huallaga R
Madeira R
Pernambuco
MONTANA
Ucayli R
Santa Anna do Sobradinho
Sao Francisco R.
R Araguaya
Callao
Lima
Bahia
L Titicaca
Cuyaba
Arequipa
Misti
La Paz
Mollendo
Paraguay R.
Arica
Sucre
20
Iquique
Parana R.
Ouro Preto
R Pilcomayo
S. Paulo
Campinas
Antofagasta
Sã do Mar
Alto da Serra
Rio de Janeiro
Santos
Salta
Asuncion
Chañaral
Caldera
Santiago
Corrientes
Parana R
30
La Serena
La Rioja
Porto Alegre
Port Tortuga
Concordia
San Juan
Santa Fe
Cordoba
Rio Grande do Sul
Valparaiso
San Luis
Santiago
Rosario
Juan Fernandez
Uspallata
Buenos Aires
Monte Video
Plate R
Azul
Bahia Blanca
NEUQUEN
Rio Negro
40
Valdivia
Pt Galera
RIO NEGRO
CHUBUT
English Miles
0 100 200 300 400 500 600
50
Santa Cruz
Evangelist's Is.
Dungeness
Punta Arenas
Tierra del Fuego
Ushuaia
Cape Horn
90
80
70
60
50
40
30
20

FIG. 123. Key map, showing the position of places mentioned in the text.

Guiana. Practically all the continent as far south as the tropic of Capricorn, except the west coast region, has a mean monthly sea-level temperature of over 70° in every month. The south of the continent is much warmer in winter and cooler in summer than the same latitudes in North America and Asia. In the southern winter the 32° isotherm remains south of Cape Horn; but in China it curves equatorward as far as the 35th parallel in January. The narrowness of the continent, and the vastness of the surrounding oceans, preclude any extreme continental winter in South America. And the same causes produce remarkably cool summers, for in January the 50° isotherm crosses Tierra del Fuego in lat. 55°; in the northern continents this isotherm is found in general

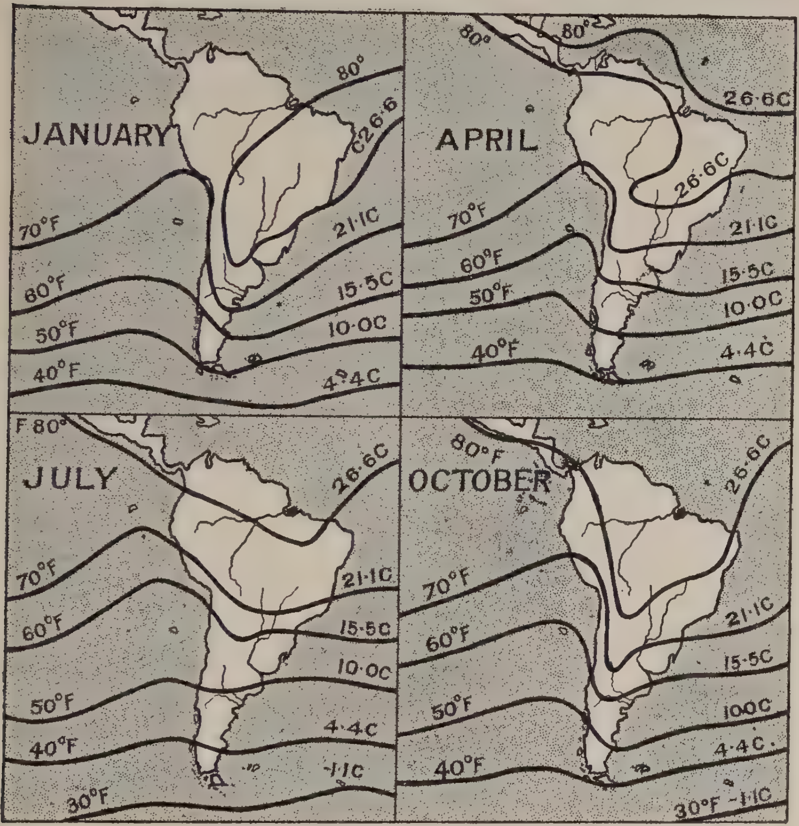

JANUARY
80°
C26·6
70°F
21·1C
60°F
15·5C
50°F
10·0C
40°F
4·4C
APRIL
80°
80°
26·6C
26·6C
70°F
21·1C
60°F
15·5C
50°F
10·0C
40°F
4·4C
JULY
F 80°
26·6C
70°F
21·1C
60°F
15·5C
10·0C
50°F
4·4C
40°F
-1·1C
30°F
OCTOBER
80°F
26·6C
70°F
21·1C
60°F
15·5C
50°F
10·0C
4·4C
40°F
30°F -1·1C

FIG. 124. Mean Temperature. (Buchan.)

beyond the Arctic circle. Off the west coast of South America from Cape Horn to the Equator the isotherms show a very pronounced northward bend throughout the year. This is due to the cold waters of the Humboldt current.

Oceanic Conditions. The Antarctic current, moving from west to east, meets the coast of Chile in about 40° S. lat., and spreads to north and south. The north-flowing branch is the Humboldt current, which is blown along as far as the Equator by the south-east trades. Owing to its direction it is a cool current, but close inshore there is still colder water, which wells up from the depths of the ocean to take the place of the surface layers which the trades waft towards the north-west. The main features of the climate of the coast are to be attributed largely to this cold water; there is much fog and cloud, but hardly any rain, and the temperature is remarkably low.

The other branch of the Antarctic current flows south off southern Chile and shows no great abnormality of temperature; the prevailing winds are on-shore, and hence there is no upwelling cold water along this coast. The west coast of Colombia, between the Equator and the isthmus of Panama, is beyond the reach of the Humboldt current, and is washed by the warm waters of the equatorial counter current.

On the east coast of the continent there is warm water nearly everywhere. The south equatorial current of the Atlantic meets the Brazil coast at Cape St. Roque, which, projecting like a wedge, divides this great stream into two branches, one of which flows past the Amazon mouth, the Guianas, and Venezuela, into the Caribbean Sea, while the other goes southward as the Brazil current and reaches the Plate estuary. Beyond this we find cool water derived from the Antarctic, in the Falkland current, flowing north from Cape Horn.

Pressure (Fig. 125). The swing of the equatorial low-pressure system with the sun is similar to what we have traced in Africa. In April the lowest pressures are over the Equator. As the sun enters the northern hemisphere the low-pressure trough follows, and in July it covers the continent from the Equator to the north coast, and runs far north over Central America to join the low pressures over North America. By November it has returned to the Equator, and in January it is at its farthest south, over southern Brazil. Over the oceans the doldrums migrate less. On the Pacific coast and the adjoining waters they remain north of the Equator even in the southern summer, since the cold water off the coast south of the Equator is unfavourable to low atmospheric pressures. Over the Atlantic ocean the doldrums migrate only a few degrees, being just north of the Equator in August and just south of it in February.

The subtropical high pressures of the southern hemisphere are centred in July about lat. 30° in the Pacific, and lat. 27° in the Atlantic, and a band of high pressure crosses the continent. The isobars show a near approach to the theoretical 'belt' of high pressures. In January the high-pressure belt is broken over the heated continent, and there are detached anticyclones over the oceans; the pressure at their centres is somewhat less than in July, but the gradients are steeper. The Pacific system covers much of the coast of central Chile, giving it fine dry weather. Poleward of the anticyclonic belt pressure diminishes rapidly and uniformly towards the low pressures, which form another belt right round the globe about lat. 60° S.

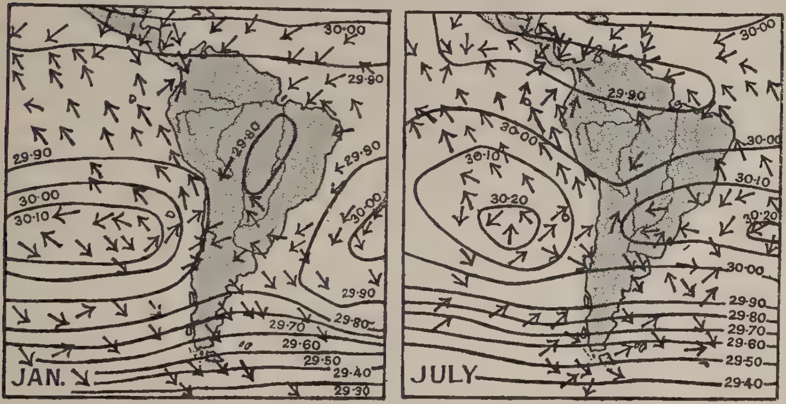


Fig. 125. Mean pressure and prevailing winds. (Buchan.)

Prevailing Winds. The north coast of Colombia, and the coasts of Venezuela and the Guianas, have north-east trade winds all the year, strongest and steadiest in January, weakest and often interrupted in July, when the doldrums belt is close to the coast; the latter is the rainy season. The Amazon basin experiences a double pressure wave in the year, as the low pressures make their way north and south with the sun; the heaviest rain falls at the Equator near the time of each passage of the sun, and the trades make their influence felt during the intervening months, blowing from the north-east in January, and from the south-east in July. There are but few detailed observations to establish this, but probably it is correct as a general statement.

The east coast of Brazil from Cape St. Roque to the tropic has easterly winds in all seasons, south-east in July, east and north-east in January, when there is a monsoonal inflow to the heated interior. We have observed that the doldrums belt migrates only from British Guiana to the mouth of the Amazon, and this coast has weak and variable north-east and south-east winds in January and July respectively.

The coast between the tropic and the Plate estuary is on the west side of the South Atlantic anticyclone all the year, and hence has north-east winds, warm, moist, and rainy. We may contrast this with the regular monsoonal change on the east coast of Asia in the same latitudes, where the land mass is sufficiently large to produce very high pressures and outblowing winds in winter.

On the west coast of South America the winds blow parallel to the coastline and the Andes, except in the south. On the coast of Colombia they are south-west and variable all the year, and there is heavy rainfall in every month. In general the lofty barrier of the Andes cuts off the surface air circulation of the Pacific from that of the Atlantic and the interior of the continent. In Colombia the barrier is not very important since the ranges trend from north-east to south-west, parallel to the direction of the trade winds which blow most of the year. But south of the Equator there is little doubt that the mountains form a complete barrier. The south-east trade winds of the Pacific Ocean are associated with the anticyclone of that ocean and have not crossed the continent from the Atlantic. The aridity of the west coast cannot be attributed to the prevailing winds having been robbed of their moisture in crossing the Andes.

South of lat. 40° S. the Andes are still a continuous range, but the altitude is much less and the stormy westerlies are able to cross them; probably the great thickness of the air stratum involved in the westerlies helps them to surmount the barrier. Their ascent gives south Chile its excessive rainfall, and their descent causes the rain shadow of Patagonia, where the annual rainfall is less than 10 inches. The winds of the westerlies are very strong, and variable in direction, but the resultant air movement is from west to east. The low-pressure belt is the scene of

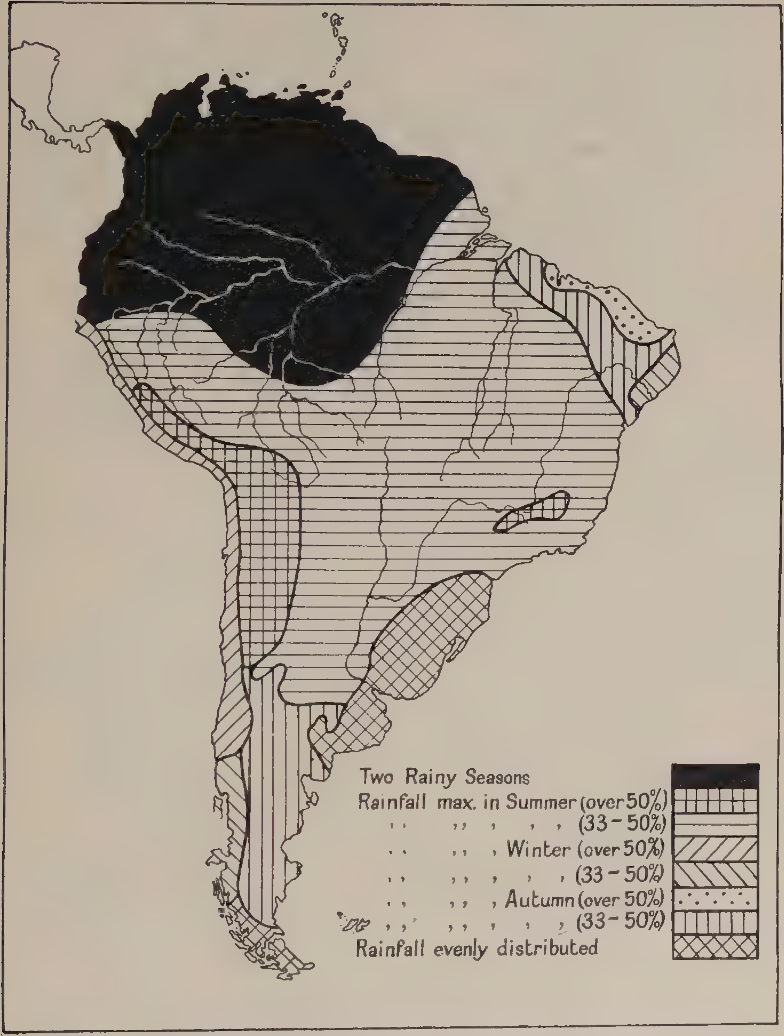

Two Rainy Seasons
Rainfall max. in Summer (over 50%)
" " " " (33 – 50%)
" " Winter (over 50%)
" " " " (33 – 50%)
" " Autumn (over 50%)
" " " " (33 – 50%)
Rainfall evenly distributed

FIG. 126. The seasonal distribution of the Rainfall of South America.

a procession of numerous cyclones, round which the barometric gradient is usually very steep. The wind swirls into them with great violence, and this region of the Roaring Forties is probably the wildest on the Earth. Since most of the cyclones pass south of Cape Horn, the whole of this coast of South America is usually under the influence of winds from a northerly direction, and the climate is, therefore, mild and very moist. The rainfall,

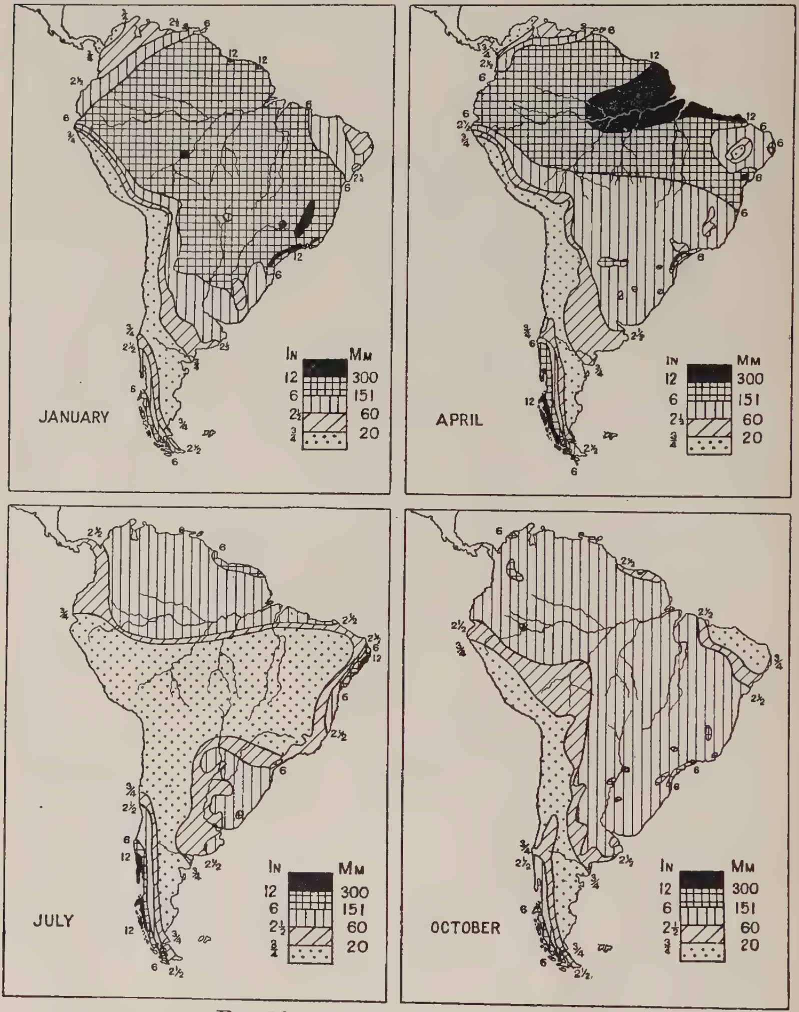


Fig. 127. Mean monthly Rainfall.

heavy in any case in this stormy area, is especially great owing to the mountains. The climate and weather sequence is much

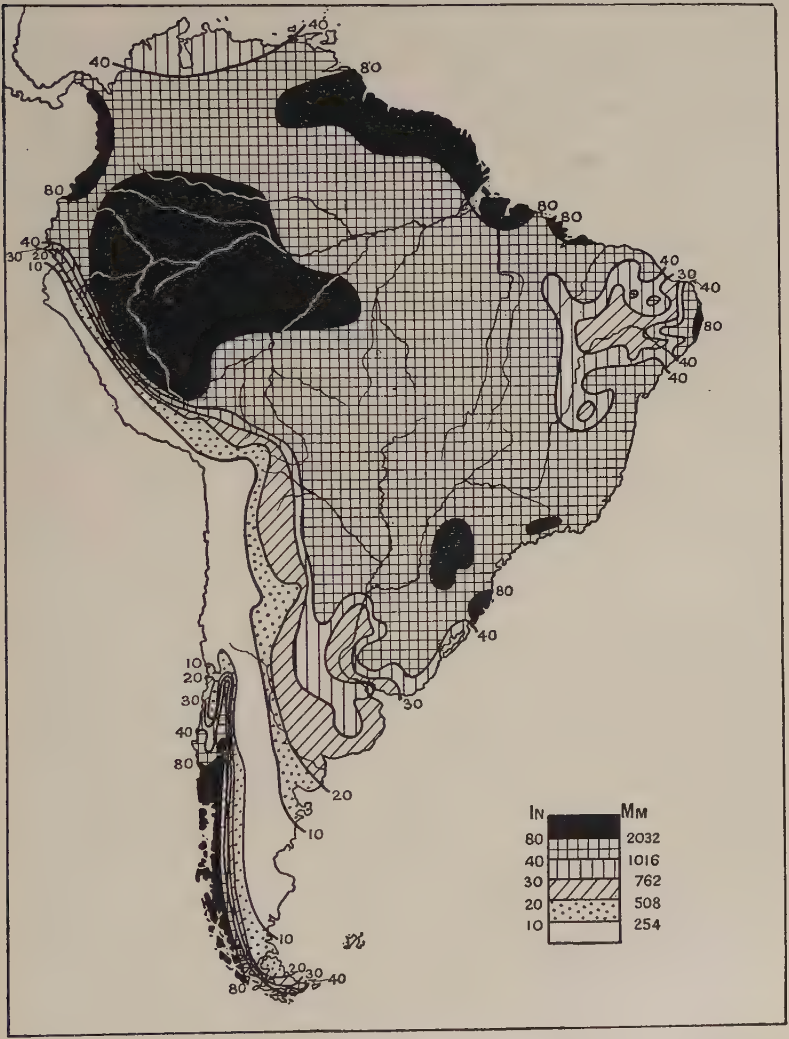

40
40
80
80
40
30
20
10
80
80
40
30
40
80
40
40
80
40
30
10
20
30
40
80
20
10
10
20
30
40
80
In
Mm
80 ■ 2032
40 ⊞ 1016
30 ▥ 762
20 ▨ 508
10 ☐ 254

Fig. 128. Mean annual Rainfall.

like that of the north-west of Europe, which occupies a corresponding meteorological position. A mild northerly wind heralds the approaching depression, the sky is overcast with driving clouds, and there is heavy rain. As the depression passes on towards the east the wind veers to the north-west and west, and often blows furiously.

The Roaring Forties extend farther north in winter than in summer, and central Chile comes under their influence. The region round Santiago has, therefore, mild rainy winters, and fine rainless summers, that is to say the 'Mediterranean' climate type.

Rainfall. By far the greater part of the continent as far south as lat. 35° S. receives its rain in the hot season (Figs. 126 and 127). The double rainfall maximum of the equatorial zone can be traced from the north coast to about 10° S. lat., but, except on the Equator itself, and on the Andes for some distance north and south of the Equator, there is really one long rainy season, with two maxima of specially heavy rain. The rainfall of the whole west coast from Ecuador to central Chile is anomalous in season and notably scanty in amount; for what little rain there is, falls in the coolest months. South of lat. 35° S. there is in most parts much rain in all seasons, but most in autumn and winter.

The Andes of Colombia and Ecuador have heavy rainfall (Fig. 128). South of this, as far as about 30° S. lat., the east slopes of the Cordillera are very moist, but the west are dry; and in south Chile the western slopes have excessive rain, the eastern slopes little. The subtropical high-pressure belt crosses the Andes at about 30° S. lat., and hereabouts it is very dry on both sides of the range. The eastern slopes face the prevailing winds north of the high-pressure belt, the western slopes south of it.

CHAPTER XXXVII

THE WEST COAST, SOUTH OF THE EQUATOR

This region comprises the long strip between the shore and the upper slopes of the western Cordillera of the Andes. Nearly everywhere along the west coast of South America a coastal range rises steeply from the ocean. Its elevation is never much more than 5,000 feet, so that it is insignificant by comparison with the giant ranges inland (Fig. 129), but yet it is high and continuous enough to shut out the true maritime climate from the longitudinal valley between it and the Andes. The coast range is drowned in the south, and forms the islands of south Chile.

From the Gulf of Guayaquil, almost as far as Valparaiso, it is an arid land, subject to the trade winds all the year. The Andes entirely shut out the winds of the Atlantic Ocean and the interior of the continent. The land is warmer than the sea, and there is a constant tendency, especially by day, for the south-east trade of the Pacific to be attracted, becoming a south wind; thus the prevailing winds on the coast itself blow parallel to the mountain ranges. There is no rain, since the trades are, by their nature, dry winds, and when they reach the warmer land from the cold water which washes the coast their humidity is still further reduced. The coast range sometimes receives a very little rain when the breeze from the sea is more than usually moist; but in the valley east of the coast range the chance of rain is always small. The only streams of water are those derived from the snows and rains of the lofty Cordillera, and these form strips of verdure crossing the arid sand at distant intervals.

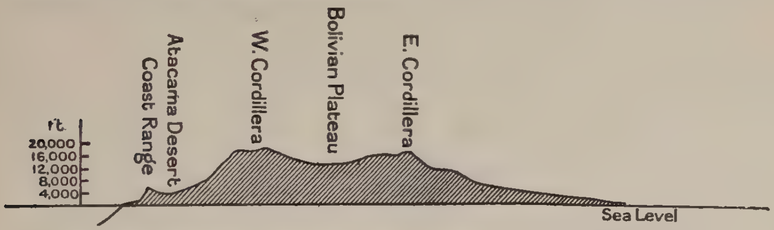


FIG. 129. Section across the west of South America in lat. 20° S.

The northern frontier of Peru forms a true physical, not less than a political, division, for it marks the sudden change from excessive to scanty rainfall; on the north coast of the Gulf of Guayaquil there is more than 40 inches of rain in the year, on the south coast Tumbez receives only about 10 inches, and southward for more than 2,000 miles there is less than 10 inches. At Lima the mean rainfall is 2 inches, and nearly all of it is received in the months June to September; heavy showers are rare, the usual rain being a fine drizzle or a wet mist called Garua, which suffices to call into life a bright show of vegetation after the arid months. The air is often very moist, though the amount of rainfall is that of a desert. A thick pall of cloud may lie for weeks over the coast, and sometimes rests on the surface of the earth, forming the misty fogs, Garuas, just mentioned. Darwin describes them in these words: 'A dull heavy bank of clouds constantly hung over the land, so that during the first sixteen days I had only one view of the Cordillera behind Lima. It is almost become a proverb that rain never falls in the lower part of Peru. Yet this can hardly be considered correct; for during almost every day of our visit there was a thick drizzling mist, which was sufficient to make the streets muddy and one's clothes damp; this the people are pleased to call Peruvian dew.' Winter is the cloudiest and dampest season along all this coast—an interesting anomaly for a tropical region, which finds its explanation, apparently, in the fact that the land is then relatively coolest, and the warmer air from the sea is chilled to dew point over it. The fog, cloud, and precipitation are heaviest on the coast, the interior being sheltered by the coast range. From the sea the coast may often be seen to be enshrouded in cloud, while through the gaps in the hills a glimpse is caught of the landscape beyond bathed in bright sunshine.

On the east of the longitudinal valley, that is to say, on the west slope of the Andes, above 7,000 feet near Arequipa, the rainfall increases; but here summer is the rainy season, and the rain falls in heavy showers, which are derived from the clouds blown over from the Andean plateau; Arequipa has an annual mean of about 6 inches. The mountain streams fed by this rain provide facilities for irrigation at the foot of the mountains, which enables cotton to be grown. This summer rain belt descends lower and lower towards the Equator, and finally merges with the coastal equatorial rains about Guayaquil. Thus there are along the coastal belt of Peru and northern Chile, three rainfall regions parallel to the coast—a very arid central strip; on the seaward side of it a region with drizzle-rain, mostly in winter; and on the other side the upper slopes of the Cordillera, with summer rain.

Temperature is remarkably low and uniform on the west coast. At Callao, 12° S. lat., the annual mean is 67°, at Mollendo, 350 miles farther south, 65°; contrast Bahia, on the coast of Brazil in the same latitude as Callao, where it is 77°. The highest temperatures recorded rarely exceed 80°. When we leave the cold current and go inland we find only a very slight fall in temperature in spite of the increasing altitude, till we reach the steep slope of the Cordillera; Lima, though 520 feet above its port Callao, is less than half a degree cooler. The annual range of temperature is only 8° at Callao, 13° at Lima. February is the warmest month in most places, but March at Callao.

We find the aridity of Peru in an intensified form when we pass the bend in the coast line at Arica and enter Chile, which may be truly described as rainless even on the coast; for the rare and uncertain showers are quite valueless for vegetation. The prevailing wind blows from the south-west; rarely is any other direction experienced at Iquique, where out of 1,000 observations (8 a.m., 2 p.m., and 9 p.m.) 420 are calm, 475 south-west, and only 105 from all other points. At Juan Fernandez, an island lying some hundreds of miles out in the open ocean, the predominant directions are south-east and south. The cold Humboldt current is equally prominent here as off Peru, with similar results. The moist sea air at Iquique, where the mean monthly relative humidity varies from 74 to 77 per cent., is said to be very destructive to furniture, and to cause all bare iron to rust. But the mist-drizzle which we found at Callao is not a feature of the climate. At Iquique during five years no rain at all fell in the first four, and a heavy shower gave 0·6 inches in July of the fifth year; thus the mean annual rainfall of the period was 0·1 inch, and winter is the ‘rainy season’. On another occasion a single shower gave 2·5 inches. We may best describe the climate as rainless, but liable to a heavy shower at long intervals. On the average there is only one rainy day a year; it has been well said that on this coast a week of rain is much rarer than an earthquake. Other stations with annual means of less than 1 inch are Mollendo, Antofagasta, and Caldera. South of this the rainfall increases steadily. Chañaral Island has 3·4 inches, La Serena 4·3 inches, Port Tortuga 6·7 inches, and on one occasion 5·5 inches fell here within 16 hours. At Valparaiso we have left the arid tract, and find 22 inches. The fogs to which the arid coast is subject occur especially with winds from north and east. The sky is cloudy for the latitude in winter; it is cloudier in August at Iquique than in the British Isles. The cloud layer rests on the mountains about 2,000 feet above the sea, and supports a belt of vegetation which is almost entirely dependent on it for moisture. In summer the Chile coast is sunny, the mean cloud covering being only three-tenths in February. As in Peru the temperature is remarkably low, and the range small. On an average day in summer the thermometer does not rise above 75° even at Arica, nor fall below 55° in winter. The uniformity of temperature which we noticed on the Peru coast is continued in Chile; at Callao the annual mean is 67°, at Arica 65°, at Iquique 66°, and at Antofagasta 65°. Southward the temperature is somewhat lower, but at Valparaiso it is still 61°.

Behind the coast range the aridity is at a maximum. In the nitrate fields of the Atacama desert, shut off from the sea mists, the air is very dry, and even the slightest shower is exceedingly rare. A few streams bring water from the Andes, and occasionally a great flood descends on the desert, when the rain in the mountains is very heavy; but at most times this is an unbroken desert of brown earth, and the air is hazy with dust and heat. Not a plant, even of the humblest form, is to be seen. The heat is greater than on the coast in spite of an altitude of 2,000 to 3,000 feet, and in summer the temperature may rise to 85° or 90°; but in winter radiation cools the ground rapidly at night, and a thick fog often settles on the desert, with a temperature below freezing-point.

The upper western slope of the Cordillera, overlooking the longitudinal valley, has the characteristics of the corresponding region in Peru, and there is a considerable rainfall in summer—evidently an extension of the summer rains of the Puna.

South of lat. 30° we are in an entirely different region; the land is no longer arid, and at lat. 40° we reach the zone of the westerlies, and enter one of the rainiest regions on the earth. The westerlies extend their influence farther north in winter, and the coast of central Chile between lat. 30° and 37° has a 'Mediterranean' climate, with rain in winter, but dry trade-wind conditions in summer. The winter rain is associated with cyclones, but nevertheless the mean barometric pressure is higher in winter than in summer. We must distinguish the comparatively cloudy rainy and equable coastal strip from the warm drier central valley. At Valparaiso on the coast the mean monthly temperature ranges from 66° in January to 55° in July, and the thermometer rarely rises above 85° or falls below 38°. The corresponding climate region of Europe is represented by Lisbon, which, however, is 400 miles nearer the Pole ; it has considerably warmer summers and cooler winters. Valparaiso has 22 inches of rain a year, 85 per cent. falling in the four months May to August. This is one of the least cloudy and foggy parts of the west coast between the Equator and Cape Horn. In the Central Valley, sheltered by the coast range, summer is warmer, but winter considerably cooler, than on the coast; Santiago, 1,700 feet above the sea, has recorded extremes of 96° and 25°. Santiago has far cooler summers than the eastern part of the Mediterranean region of Europe. The annual rainfall is 16 inches, and suffices with the available irrigation to make such fruits as peaches, grapes, and oranges flourish. Snow is not unknown, but it is very rare.

South of lat. 37° the summer months are rainier, and at Valdivia no month has less than 2 inches, but the summers have much less rain than the winters; the whole region is densely forested. Valdivia receives 110 inches of rain a year, and this is the highest record on the west coast except at Evangelist's Island, which receives 117 inches and has experienced a spell of 72 days with rain each day.

The prevailing wind directions are shown by the records from Port Galera. The winds, being controlled by the cyclones of the westerlies, are much more variable in direction, as well as stronger, than on the rainless coast of north Chile, represented in the table by Iquique.

Wind frequency (mean for the year, of observations at 8 a.m., 2 p.m., 9 p.m.), expressed in thousandths (Mossman):

	N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm.*
Iquique . .	9	16	3	15	27	475	5	30	420
Port Galera .	283	23	27	34	279	80	56	128	90
Evangelist's Is.	81	14	32	43	95	167	214	289	65

The most frequent directions at Port Galera are north, south, north-west and south-west ; winds from any easterly point are comparatively rare. Evidently the west winds are deflected by the Andes near sea level, and appear as along-shore winds, though the main air current of the westerlies crosses the mountain barrier. At Evangelist's Island the prevailing directions are north-west and west; the winds seem to be less deflected, owing to their greater strength and the less lofty barrier. Here the average speed of the wind is 35 miles an hour—about three times as great as in the south of England; and a speed of 151 miles an hour from north-west has been recorded. There is little difference in wind velocity between summer and winter. The Strait of Magellan shares these wild conditions, the violent squalls being known as Williwaws. The winter is mild in this stormy region, but summer is remarkably cool, the January mean at Evangelist's Island being only 47°. The range of temperature is small, for the absolute extremes recorded are 59° and 24°; the former figure is significant of the cool summers. Owing partly to the cool summers, partly to the excessive precipitation, the snow line on the southern Andes is as low as 2,600 feet, and glaciers reach the sea at the heads of the fiords south of lat. 46°. Records are scanty from the mountains, but the precipitation is certainly much greater than on the coast. Winter is the rainiest season on most of this coast, but summer in the extreme south.

After crossing the Andes the westerlies pass on over Patagonia as dry winds, and at the eastern base of the mountains föhn effects are often developed. The scanty rainfall of Patagonia is no doubt partly due to the cool Falklands current, since winds from the east, blowing in towards cyclones, are cool, and can give little rain. It has often been pointed out how the heavy rain of the western slopes of the Andes has caused the rivers on that side to work eastward, and capture the head waters of the feebler east-flowing streams. The rapid decrease in the rainfall is well seen from the following records:

MEAN ANNUAL RAINFALL

Evangelist's Island (off west coast) . . .	117 inches.
Punta Arenas (Strait of Magellan) . . .	15 ,,
Dungeness (East end of Strait of Magellan) . .	10 ,,

In most of Patagonia autumn, not winter, is the rainiest season, just as in the British Isles autumn is the rainiest season in the east, but winter on the west coasts. It is perhaps due to the fact that in the winter the cold land area tends to cause higher pressures over it than in autumn, and, therefore, in autumn the cyclones of the westerlies find less obstacle to their advance.

CHAPTER XXXVIII

THE ANDES PLATEAU

The plateau extends from the Equator to the tropic of Capricorn, through Ecuador, Peru, and Bolivia. Its elevation averages 9,000 feet in Ecuador, and over 12,000 feet in Bolivia. The ranges of the Andes form fairly continuous walls on both sides, with peaks more than 20,000 feet high. The region is probably above the lower atmosphere in which the winds on the west coast and in the Amazon valley circulate, and belongs to the middle atmosphere.

Quito is representative of the Puna of Ecuador, a bleak region with some cultivation, but no forests and hardly any trees. Potatoes and barley are the chief crops, and even these are not possible a few hundred feet above the town. There is perpetual snow above 15,000 feet, the snow line being rather lower on the eastern than on the western Cordillera, since the eastern side has the heavier precipitation.

Quito has a mean annual temperature 20° lower than the west coast, and, therefore, it is not so cold by comparison as might have been expected from its altitude. But this is due more to the abnormal cold of the Ecuador coast than to any remarkable warmth at Quito.

Perhaps the most striking feature is the remarkable uniformity of the temperature and weather, from day to day, and from season to season, which reminds us that Quito is on the Equator in spite of the absence of equatorial heat (Fig. 130). The temperature throughout the year is much the same as in the south of England in May. Quito is often said to enjoy a perpetual spring. The annual range is less than 1°, and the extremes are moderate, for the air temperature is rarely above 75° by day or below 35° at night. The rarefied air favours radiation, and hoar frost is frequent.

Though Quito is on the Equator the rainfall régime is rather that of the south hemisphere, for there is comparatively little rain in June, July, and August, and the months September to May are the rainy season. The total rainfall, 44 inches, is only about half as much as that of the Amazon valley, owing partly to the low temperature.

Travellers are agreed that if Quito has a perpetual spring, it has the unpleasant, rather than the pleasant, features of that season, with violent changes from hot sun to chill wind and snow. The complex sequence of the daily weather is a great contrast to the uniformity of the climate from month to month. The night and early morning are cold and raw, but the powerful sunshine raises the temperature rapidly, and by noon it feels hot in the sun, though in the shade it is still cool. About midday clouds gather and there is often a violent thunderstorm in the afternoon with heavy rain, hail, and frequently snow. These clouds and storms are essentially convectional, and they die away after the heat of the day which caused them. Hann has computed very striking figures showing the daily periodicity of cloudiness. He finds that during the rains only two afternoons a month are clear. In the whole year it is clear at noon on only forty-five days, but at sunrise clear skies are more than three times as frequent. The early mornings are fine, and the air at these great altitudes is remarkably clear; but in the afternoons the clouds hang low over the gloomy landscape, and hail, snow, and rain chill the air, so that the mountains are almost invariably hidden.

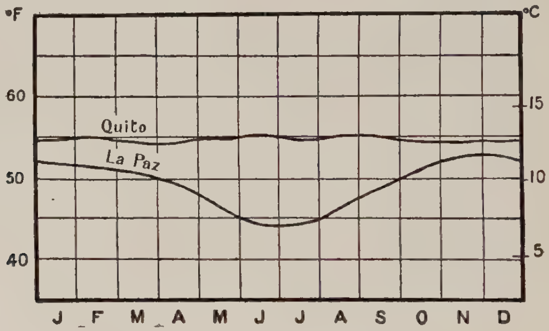


FIG. 130. Mean Temperature.

Bolivia, being at a distance from the Equator, has considerable seasonal changes. Owing to its generally clearer skies the temperature is somewhat higher than in Ecuador if we make allowance for the greater altitude of Bolivia. At La Paz, lat. 16·5° S., the warmest month, November, is 9° warmer than the coolest, June (Fig. 130). The rainy season is summer, when the overhead sun causes convectional rainfall. The rains begin in November and last till March or April. The weather is warmest just before the rains set in in earnest. May, June, and July are almost rainless. The daily cycle of weather during the rains is the same as has just been described for Quito. The morning is clear, but as the heat increases masses of cloud are seen rising on the eastern Cordillera, and pouring through the gaps from the moist montaña on the farther slope of the mountains. They overspread the sky, and usually produce a violent thunderstorm. The loudness of the thunder is always commented on by those who have described the region; perhaps the electrical phenomena are especially intense, or perhaps the peals are merely intensified by the echoes from the mountain walls. During the rains the rivers swell, and Lake Titicaca rises to 5 feet above its winter level. But the air is very dry in the dry season; the plateau is a region of continental drainage. Sir Martin Conway observed during his mountaineering expeditions that there was remarkably little water derived from the melting of the ice of the glaciers, and remarkably few avalanches, and he attributes these facts to the rapid evaporation of the snow and ice.

The range of temperature from day to night is much greater than from summer to winter. Owing to the clear dry air radiation is very effective, and frost is recorded at La Paz in every month of the year. Probably during the dry season it freezes every clear night, and Lake Titicaca is frozen round its shores. But the sun's rays are powerful, and in the dry season it is usually about 25° warmer at midday than before sunrise. The contrast between sunshine and shade is great. Sir Martin Conway gives us a vivid picture of the weather:

> ' Early in the morning and late in the evening, when the sun is below the horizon, the cold is liable to be intense even in September and one suffers from almost frozen feet. In the winter, when the winds blow and the frosts are yet more severe, the dry cold is so trying that even the natives cover up their faces in thick woollen masks, and wrap shawls about their heads and ponchos over their bodies. But as soon as the sun is a little way above the horizon, its direct rays scorch the traveller with their great heat, so that he soon begins to pray for the night, as the

lesser evil of the two. . . . By day the burning sunshine so envelops all the brown, dry, dusty ground that everything in view seems to vanish in brightness ; and the eye, unprotected by dark glass, cannot gaze steadily in any direction. . . . When the sun is hottest little cyclones raise dust whirlwinds which dance along, often by scores at a time.'

The air pressure on the Puna is only about 20 inches of mercury, and visitors suffer much discomfort from mountain sickness. Even natives who have to travel from the coast to the Puna are not immune. The ' soroche ', as the complaint is called locally, causes breathlessness and palpitation, loss of appetite, and sometimes nose-bleeding. Colds are another very common complaint at these high altitudes.

Above 13,000 feet are the bare uncultivable paramos, up to about 18,000 feet, where perpetual snow begins. As in Ecuador the snow line is lower on the side of the moist Amazon valley than on the west.

On the Andes south of the Bolivian plateau an interesting feature is the wind, which often blows with excessive violence especially by day, so that all traffic is held up. The temperature may be below freezing-point and the sky quite clear all the time.

CHAPTER XXXIX

SOUTH AMERICA NORTH OF THE EQUATOR

Colombia, Venezuela, and the Guianas make up most of this region. Speaking generally, the climate is that usual in the tropics of the northern hemisphere, and it may be compared with that of the Sudan. The north-east trades blow on the coast all the year, strong and steady in January, while the equatorial low pressures are over southern Brazil; but in July when they have moved north, almost to the north coast, the trades are interrupted by calms and variables, especially inland where west and north-west winds blow. There are two seasons sharply contrasted, the dry and the wet. The former is the northern winter, when the trades sweep the whole region (except the west coast of Colombia, which will be described later). They contain abundant moisture, picked up as they cross a warm sea, but as they are travelling to warmer regions they do not precipitate it except on the windward side of the mountains, such as the north slopes of the Sierra Nevada de S. Marta. From the llanos there are no long series of records, but all accounts tell of an almost rainless period from the end of November till the middle of March, with very clear skies and dry air. April brings a great change. With heavy clouds and much thunder and lightning, the rains begin, and last for 8 months, during which the low-pressure trough is over the region. The rain is heaviest in May and June and in September and October, a fact which seems to be connected with the passage of the overhead sun. The break in the heavy rain in July and August is apparently caused by the low-pressure trough sometimes moving slightly north in those months, drawing with it the land breezes from the south. Here, and in other parts of Spanish America, the rainy season is called ‘ invierno ’, winter, and the dry season, ‘ verano ’, summer—the popular language appreciating the meteorological rather than the astronomical aspect.

The inter-Andine valleys of Colombia have similar seasons. At Antioquia the heaviest rain is in the months April to June and August to November, July being somewhat drier ; December to March is a dry period. But Bogota, 8,730 feet above the sea, on the Andes, has an equatorial régime, rain all the year, with maxima in the periods March to May and October to December, July being the driest month. The great valleys of the Magdalena and Cauca have abundant rain almost everywhere, owing to the fact that they open towards the north-east, whence the prevailing winds blow ; but the upper part of the Magdalena valley, south of lat. 5° N., has less rain, and poorer vegetation. The daily cycle of the moisture in the atmosphere is a prominent feature in these valleys. In the night and early morning the bottoms are often hidden in a lake of white mist. The mist dissolves when the sun rises, and before midday clouds collect round the mountain tops, whither the valley breezes have transferred the moisture. At night the clouds disappear and the valleys fill with cold fog again.

The west coast of Colombia has few records, but it is certainly a very rainy district, and probably rainy in every month, with a slight intermission in the rains from December to April. We have already pointed out that the doldrums belt remains north of the Equator here all the year, and that there is a warm current along the coast.

The Guianas have excessive rainfall, most stations recording more than 80 inches, and Cayenne over 120 inches. The heaviest rain is in May and June, when the country is flooded for miles by the swollen rivers; there is a second maximum in December or January. This winter maximum is an anomaly for which no explanation has been given; the winds are much the same all the year. This coast is fortunate in missing the West Indian hurricanes.

Temperature is remarkably uniform in all the region we are describing, the annual range being less than 5°; at Georgetown it is 3°. Near sea level the heat is great, but there are large areas in the mountains where it is moderate. Caracas, over 3,000 feet above the sea, is naturally chosen as the capital of Venezuela, instead of its port La Guayra, which is very hot, especially in late summer. But, as in all equatorial countries, no excessively high temperatures occur, 85° not being often exceeded; on the other hand the thermometer does not often fall below 70°.

In the Andes the usual division is into the following climate and vegetation zones: tierra caliente, from sea level to 3,000 feet, with a mean annual temperature from 83° to 75°, and luxuriant tropical vegetation; tierra templada, from 3,000 to 6,000 feet, temperature 75° to 65°, a belt suitable for maize and coffee; tierra fria, 6,000 to 10,000 feet, temperature 65° to 54°, where wheat and temperate fruits flourish; paramos from 10,000 to 13,000 feet, too cold for trees and cultivation, temperature 54° to 43°; above 13,000 feet there is perpetual snow. Bogota, 8,730 feet above the sea, is in the tierra fria, with a mean annual temperature of 58°; the annual range is less than 2°.

The Guianas especially, owing to the combination of a constantly high temperature with a very heavy rainfall, and very moist air and soil, are very unhealthy, and a free exposure to the trade winds, and good drainage, are essential to a European's safety. Perhaps it is its fatal climate which has won for French Guiana its chief fame as a convict settlement. Pestilential mangrove swamps fringe the coasts and creeks.

CHAPTER XL

BRAZIL, URUGUAY, AND PARAGUAY

The Amazon basin. The trade winds find ready access into the Amazon basin up the wide opening between the heights of Guiana and east Brazil, as well as over the llanos of Venezuela, and through the Argentine. Forced to ascend in the equatorial low pressures, especially when they reach the wall of the Andes, which bars the way in the west, they give a very heavy rainfall—far heavier than that of the Congo basin, the corresponding region in Africa, for the relief of that continent tends to shut out the trades from the interior. In consequence of the heavy rainfall the Amazon is the mightiest river on the Earth, and this fact reacts on the rainfall; for there is a vast water surface, especially in flood time, from which vapour is poured into the atmosphere to be condensed again as rain. Moreover, the whole region is a dense equatorial forest, and the transpiration from the trees must add greatly to the humidity of the air.

There are hardly any good series of meteorological observations available. The few records are all from the Amazon itself, and show a south hemisphere régime, the latitude being about 3° S. The annual rainfall is more than 80 inches in much of the basin; this is the widest expanse in the world with such a heavy fall. Para receives 87 inches, Iquitos 103. The rainfall is greater nearer the Andes, where the mountain influence begins to be felt. At Para the rainy season lasts from December to August, March and April being the rainiest months; the mean number of rainy days is 243 per annum. At Manaos and Iquitos the rains last most of the year, with maxima in December and March or April (Fig. 131). During the rains the winds are weak and variable, but in the dry season the trades blow freshly, and even very strongly at times, up the river. As long as the trades are strong and steady they give little rain in the lowlands. In the rainy season the mornings are often very clear, but clouds appear before noon, and the usual equatorial thunderstorm gives a copious downpour in the afternoon, so that 'before the rain' and 'after the rain' are ordinary expressions of time at Para. Even the dry season is not free from heat thunderstorms; at Para it rains, on an average, on one day in three in the dry months; in November, the driest month, the mean rainfall is 2 inches. Iquitos receives almost 5 inches in its driest month, August.

At Obidos the Amazon is lowest in November, highest in June. The Madeira is highest in February, March, and April, and lowest in September. In the Negro basin the rains begin in February, and the river is fullest in June. There is a rise of 40 feet during the rains in parts of the Amazon.

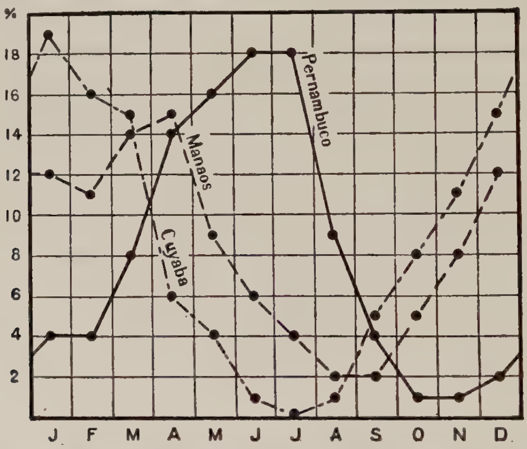


FIG. 131. Mean monthly Rainfall in Brazil, expressed in percentages of the annual total. Manaos represents the Amazon region; Cuyaba, the south Brazil, with pronounced summer rain; Pernambuco the east coast, with winter rain.

Temperature is not excessive, but is uniformly high. At Para the hottest month has a mean of 80° (compare La Guayra, 10·5° N., with a mean of 83° in its hottest month), and the maximum temperature on the hottest days does not usually exceed 90°; the highest record is 94°. The heat is considerably less than in Venezuela and in the north of the Argentine. But the nights are sultry, and at Para the thermometer has never been known to fall below 64°; the air is constantly moist even in the dry season, and the atmosphere is that of a hot-house, as in Guiana, the Guinea coast, and other equatorial lands. The mean relative humidity at Para is 93 per cent. in the rains, 85 per cent. in the dry season. The coolest months on the Amazon are during the rains, but the annual range of temperature is only some 2°. A more important relationship between temperature and season is that in the dry season the nights are cooler and the days hotter than during the rains, when the excessive cloud and moisture check radiation. The highest reading recorded at Manaos was 99°, at Obidos, 102°.

On the middle Amazon there is usually a cool spell of 5 or 6 days in May or June, brought by a south wind called ‘ friagem ’. The temperature falls about 8°, and the natives shiver with the unusual cold. The cold is probably due to the snows of the Andes from which the wind blows.

In the west of the Amazon basin is the Montaña, that is, the slopes of the Andes. Here, in spite of the distance from the Atlantic, the rainfall is very great since the mountains force the east winds upwards. In the Montaña of Peru the heaviest rains are in October and March and April, but there is abundant rain in the other months also. The air is always moist, and the forests are very luxuriant. Dense rain-forest, with rubber, vanilla, and cacao, flourishes up to about 4,000 feet. Above 12,000 feet there is nearly always thick fog. The eastern Cordillera is the main climatic divide in this part of the continent, the plateau conforming rather to the west coast than to the Amazon basin.

South and east Brazil, Uruguay, and Paraguay. Here we have left equatorial conditions, and entered the tropical climate of the southern hemisphere, with sharply marked wet and dry seasons, comparable with those of Venezuela ; the farther south we go the more pronounced does the seasonal rhythm become. The rainy season, the astronomical summer, is considerably hotter in these lands with open vegetation than in the selvas of the Amazon, but in the dry season it is much cooler than near the Equator. Thus at Cuyaba, lat. 15·5° S., one of the few stations with records in the interior of Brazil, the mean temperature in October, the warmest month, is 81°, in June, the coolest, 74°, and a reading of 43° has been recorded ; at a station situated on the tropic in long. 58·5° W. the mean in January is 84°, in June 66°, and absolute extremes of 110° and 28° are reported. On the higher plateau in the interior of São Paulo hoar frost is frequent, and snow is not unknown.

The rains are associated with the southward migration of the low-pressure system of the continent, and the replacing of the steady dry trades by variables and calms; such at least is the probable sequence, but few satisfactory records are available. At Cuyaba (Fig. 131) the rains last from October to April; the months June to August are practically rainless, and vegetation lies dormant and dried up, to wake to new life in the beginning of October. The rains fill the rivers, which overflow and form vast lakes and marshes. The seasons at Asuncion are similar. During the dry season the sky is almost cloudless, but the atmosphere is often hazy with dust and the smoke of savanna fires. The dry fresh air is a great contrast to the steamy heat and clouded skies of the rains.

As far south as the Plate River the rainy season is summer, except in certain regions which must now be discussed. The coast of Brazil, from the mouth of the Amazon to Bahia, is exceptional both in the amount and in the season of its rain (Fig. 126). From the Amazon to Cape St. Roque there is more rain in the summer half year than in the winter half year, but the rainiest season is autumn; Ceara has 63 per cent. of its rain in the months March to May. Conditions are still more abnormal beyond Cape St. Roque, for here June is the rainiest month; 45 per cent. of the yearly rainfall is received in winter, 38 per cent. in autumn, and October, November, and December are dry (Pernambuco, Fig. 131). No satisfactory explanation has yet been suggested for this curious variation. The same region has a remarkable low rainfall (Fig. 128). The amount diminishes southward from the Equator, as is usual where there are no mountains to cause a local increase, but the decrease is much more rapid in the east of Brazil, on and near the coast, than in the interior. The driest region is the middle course of the São Francisco, and the district to the north of the great bend in that river, a region of caatinga or dry thornwood, with a yearly rainfall of less than 30 inches, and a long winter of six almost rainless months; the rainiest season is autumn. The cause usually assigned, and considered sufficient to explain this aridity, is the existence of mountain ranges around, which prevent the ingress of the rain-bearing winds from the east and south-east. But the mountains do not seem to receive that excess of rain which would account for the deficiency beyond them. The rainfall in the caatinga is uncertain as well as scanty. A native writer, quoted by Voss, says:

> ‘As soon as the rains begin, the country, which until then had been desert, clothes itself with a luxuriant vegetation, and the coffee and sugar plantations, which seemed almost ruined, recover with a speed unknown in other lands; in a short time the cattle are strong and fat again, thanks to the abundant fodder now at their disposal. But, unfortunately, the rains often fail for one or two years, and famine with all its terrors spreads over the hapless land. Cattle die by hundreds, all business is suspended, and long caravans of refugees make their way to the coast, strewing the route with the corpses of those who succumb to hunger and thirst.’

Sievers tells us that over 25,000 such refugees died in 1878 in the town of Ceara. The most serious droughts occur in the interior of the states of Ceara, Piauhy, and Pernambuco. At the town of Ceara the annual rainfall has varied in the last 66 years from 96 per cent. above, to 66 per cent. below, the mean.

The extreme south-east of Brazil, Santa Catharina, and Rio Grande do Sul, and all Uruguay and the southern coast of the Plate estuary, have their rainfall well distributed over the whole year. In most parts summer is the rainiest season, but some places, as Porto Alegre, have their maximum in the winter months. Monte Video receives most rain in May, and the summer months are the driest; Buenos Aires on the opposite shore has least rain in winter. This region corresponds to south China in geographical position, but in China there is a summer monsoonal rainfall maximum, and much less rain in winter, though that season is by no means rainless. South America is too narrow in these latitudes to develop a great high-pressure system over it in winter, with resulting off-shore winds and drought. The South Atlantic anticyclone dominates the weather all the year, causing warm, moist, north-east winds.

On the coast between Santa Catharina and Pernambuco there is the normal régime, with most rain in summer. The amount of rain is very great in many parts, greater even than on the Amazon, wherever mountains rise in the path of the trades. Thus, owing to the influence of the Serra do Mar, Santos receives 82 inches, more than Para which is almost on the Equator. The rainfall increases rapidly up the steep slope of the Serra do Mar, to a maximum of 145 inches at Alto da Serra, 2,600 feet above the sea, near the top of the range, where even the driest month, July, has over 6 inches at an altitude of 750 feet. On the railway from Santos to São Paulo 16 inches has fallen within 24 hours; 'the rain is so continuous and heavy that the railway company, which was laying a new line in the Serra in the years 1897–9, state in their report that on 382 out of 975 work days, work had to be suspended on account of rain.' (Voss.) The lee slopes have much less rain, São Paulo only 56 inches a year, and here July has less than 1 inch. Rio de Janeiro has the comparatively small rainfall of 43 inches, but the air is always moist owing to the strong on-shore winds. The temperature has never been known to exceed 99° or to fall below 50°; at Hong Kong, off the coast of China, in almost the same latitude, freezing temperatures sometimes occur.

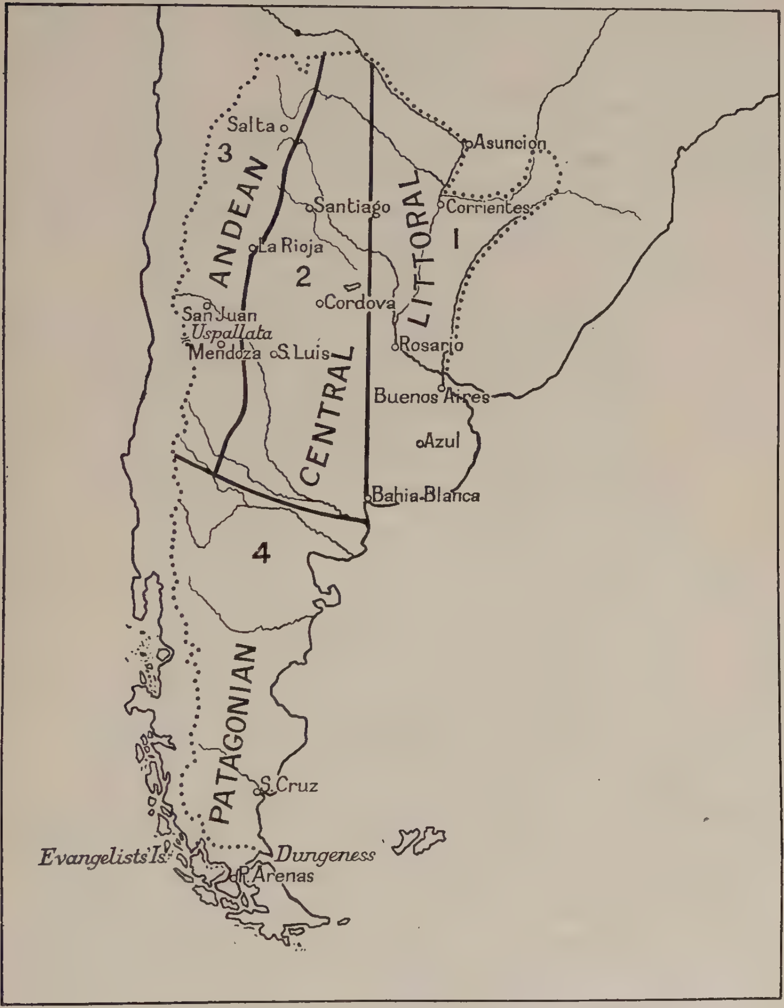
The plateau of São Paulo between the coast ranges and the Parana River contains the best coffee estates of Brazil. But the sites for the plantations must be chosen with care, for the coffee plant cannot stand much frost and the cold is considerable here in the dry season. The keenest frosts occur in the valley-bottoms; and by avoiding them and also the highest parts of the plateau very suitable conditions are obtained. Altitudes between 600 and 2,500 feet are best.

CHAPTER XLI

THE ARGENTINE REPUBLIC

The Director of the Argentine Meteorological Office divides the republic into a northern and a southern region, separated by the Rio Negro (Fig. 132). The northern division is subdivided into the Littoral province 1, the Central 2, and the Andean 3, longitude being as important as latitude. The Littoral is, of course, the most maritime, the Andean province the most continental, and in much of the latter the control of climate by altitude is important. 1, 2, and 3 agree in having most rain in summer; the periodicity is most pronounced in 3.

The mean monthly temperature and rainfall at typical stations, given on pp. 341 and 343, illustrate the main differences between the various provinces, and the following table gives some additional information with regard to the temperature conditions in the three northern provinces. It must be remembered that the Andean province contains a large area with mountain climate—in parts the mountains are capped with perpetual snow.



Salta
3
ANDEAN
Asuncion
Santiago
LITTORAL
Corrientes
1
La Rioja
2
Cordova
San Juan
Uspallata
Mendoza
S. Luis
Rosario
CENTRAL
Buenos Aires
Azul
Bahia Blanca
4
PATAGONIAN
S. Cruz
Evangelists Is.
Dungeness
P. Arenas

FIG. 132. The main climate divisions of the Argentine.

Station.	*Alt. Feet.*	*Mean annual Range.*	*Mean daily Range.* *Summer.*	*Mean daily Range.* *Winter.*	*Absolute Maximum.*	*Absolute Minimum.*
Littoral.		°F.	°F.	°F.	°F.	°F.
Buenos Aires	72	23	18	12	103	23
Corrientes	—	20	—	—	109	33
Central.						
Santiago	660	25	—	—	115	27
Cordoba	1,437	23	21	22	111	16
Andean.						
San Juan	2,139	31	—	—	114	22

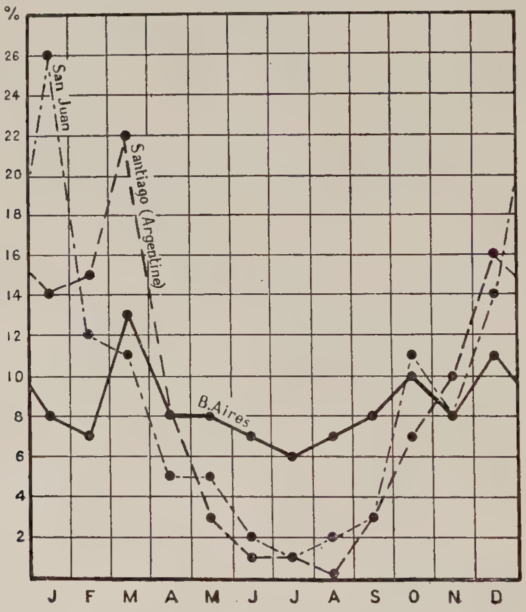


FIG. 133. Mean monthly Rainfall (percentage of the annual total).

The range of temperature is greater in the two western provinces than near the sea, and the highest temperatures are considerably higher, and the lowest somewhat lower. Even the extreme north of the Republic has recorded slight frost in winter, and in the centre and south frosts are sometimes severe enough to damage crops. The highest temperature on record which may be considered reliable is 116° at Chilca (in Santiago del Estero); the lowest — 27° in the south of Chubut (in the Patagonian climate province), and here, and everywhere south, frost may occur even in the warmest month.

The provinces differ widely in respect of rainfall. In the first place the three northern provinces show, in general, a very rapid diminution from east to west in the mean annual amount, from more than 30 inches in most of the Littoral to less than 8 inches in much of the Andean province; that is to say, we have the difference between a well-watered land near the coast, and a dry tract in the interior, where the streams wither away in the arid sands. Though the rain falls mostly in summer nearly everywhere, yet the excess in that season is not very marked in the Littoral; indeed, at Buenos Aires, autumn is rainier than summer. The following statistics show the rapid decrease in the proportion of winter rain towards the west. At Buenos Aires 56 per cent. is received in the six months October to March, at Cordoba 75 per cent., at San Juan 83 per cent., and at Salta 92 per cent., the periodicity being at a maximum here (Fig. 133).

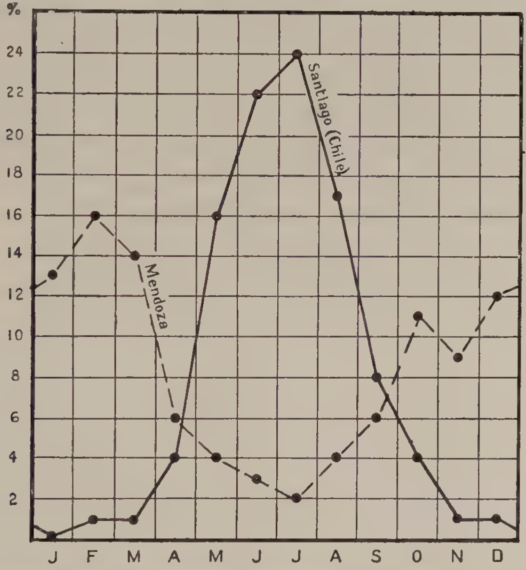


Fig. 134. Mean monthly Rainfall (percentage of the annual total); Santiago (Chile) has a very pronounced winter maximum, Mendoza (Argentine) a marked summer maximum.

Seasonal Percentage of Rainfall

	Spring.	*Summer.*	*Autumn.*	*Winter.*
Buenos Aires . .	26	26	29	19
Rosario . . .	25	35	29	11
Santiago . . .	20	45	32	3
Cordoba . . .	27	48	22	3
San Juan . . .	21	52	22	5

Fig. 134 shows how sharply contrasted are the rainfall curves on the two sides of the Andes in these latitudes.

The rainfall is very uncertain everywhere, some years having much more than the mean, others much less. How serious the deficit may be is seen from the following figures :

RAINFALL (inches)

	Mean Annual.	*Most ever recorded in a year.*	*Least ever recorded in a year.*
Buenos Aires . . .	36	80	21
Cordoba	28	40	16
San Juan	2	6	0

The distress caused by drought is most serious in the arid Andean province, but the Central province also has suffered very much. Sometimes the drought lasts two or three years ; at San Juan a spell of 671 consecutive days without rain has occurred, at Cordoba a spell of 103 days. A dry summer is the more calamitous owing to the fierce, almost continuous, sunshine.

The decrease in the humidity of the air, and in the cloudiness, towards the west is shown by our next table :

	Mean Rel. Humidity.		*Sunshine per annum.*	*Mean Cloudiness.*	
	Driest month.	*Dampest month.*		*Clearest month.*	*Cloudiest month.*
	%	%	hours.	tenths.	tenths.
Buenos Aires .	69 (Jan.)	87 (June)	2,396	4 (Jan.)	6 (June)
Cordoba . .	56 (Sep.)	73 (Mar.)	2,728	5 (Aug.)	6 (June)
San Juan . .	44 (Nov.)	60 (June)	—	3 (Dec.)	3 (June)

A striking weather phenomenon in the northern provinces, and over the Plate estuary, is the Pampero. In the Argentine the weather is controlled by the passage of cyclones and anticyclones, moving usually towards the east. The indraught from the north in front of a depression is warm and rainy, but as the depression passes on there is often a violent line-squall (Pampero) behind it from a southerly or westerly quarter, which brings with it a much lower temperature. The squall often lasts only a few minutes ; but its violence, together with the striking roll of cloud which accompanies it—usually producing rain, and sometimes thunder—and the turmoil of dust blown up from the pampas, make it very noteworthy, and shipmasters have reason to fear it. It may be compared with the Southerly Bursters of Australia, which appear to be of precisely the same type. In the north-west of the Argentine there are sometimes hot sultry breezes from the north, known as zonda.

Some main features of the climate of the Patagonian region, 4, have been pointed out already (p. 318). The summers are cool, the decrease in temperature from north to south being more rapid in that season than in winter, when Patagonia is remarkably mild for the latitude. The temperature is always highest near the sea coast. The heaviest rainfall is in the mountains ; the province of Neuquen, the Switzerland of the Argentine, has the greatest totals of the whole republic ; the rainfall decreases very rapidly towards the east, the interior of the provinces Rio Negro and Chubut having less than 8 inches. Most of Patagonia is in the rain shadow of the Andes, since the region is in the belt of the stormy westerlies.

CHAPTER XLII

MEXICO, CENTRAL AMERICA, AND THE WEST INDIES

Speaking generally, this region lies between the subtropical high pressures of the Atlantic and the equatorial low pressures all the year, with the result that the prevailing winds in every month are the trades, blowing from almost due east. There is little to add to this statement in the case of the West Indies, which are right in the main current of the trade winds, for their area is too small to produce any important local modification. But the winds are more complex in the neighbourhood of Mexico, for the off-shore winds of Texas in winter continue their course down the east coast of Mexico as far as Yucatan. They are cool winds, and when Texas is under the influence of a ‘ norther ’ the cold is sometimes felt even in Central America and the Gulf of Tehuantepec. Cool winds from the north, a continuation of the cold waves of the United States, occur in January in Jamaica and other western islands of the West Indies. The thermometer falls to freezing-point occasionally on the northern part of the Gulf coast of Mexico. In summer the east coast of Mexico has east and south-east winds, since the land is then hot, and the air is drawn towards it. On the west coast of Mexico the prevailing wind is north-west, blowing down the Gulf of California, all the year; it blows somewhat on-shore in summer. On the west coasts of Central America north-east winds (' Papagayos ') predominate in winter, strong south-west winds (' Temporales ') in summer.

Summer is the rainy season; but since most of the islands are mountainous, the trade winds are cooled below the dew point in crossing them even in winter, so that the windward slopes, and especially the higher parts, receive a good rainfall all the year. The lee coasts are fairly dry in winter. In summer the cooling of the trades by forced ascent over the mountains is assisted by convection, and the resulting rain is far heavier both on windward and leeward coasts. Hence position on windward or leeward slope is a most important factor in determining the climate. For example, in Jamaica the mean annual rainfall at Kingston on the south coast, under the lee of the mountains, is 36 inches, at Port Antonio on the north-east coast, 139 inches, and at Blue Mountain Peak, 7,400 feet above the sea, 175 inches. At Port Antonio, the driest month of the year, March, has nearly 5 inches of rain, and at Blue Mountain Peak, 8 inches, so that there is no dry season. But Kingston has only about 1 inch in each of the months January, February, March, and April, and here these months form a pronounced dry season. At most stations in Jamaica and the neighbouring islands there are two maxima in the rainfall curve, the first in May and June, and the second, rather more pronounced, in October and November; in July there is a break in the rains, this being one of the driest months. The second maximum is partly due to the heavy rainfall which accompanies hurricanes. The curve of barometric pressure is the opposite of that of rainfall; pressure is highest in the winter months, and again in July the North Atlantic anticyclone extends its influence farther over the West Indies. In the more southern islands of the Windward group the first rainfall maximum is delayed till August, and there is no appreciable drop before the next maximum—the rainy season continuing from June to December.

The rain of the summer months falls in heavy thunderstorms in the hottest hours of the day; but in winter the rain is lighter, often a drizzle, and lasts longer, and not such a large proportion falls in the afternoon.

At times there are excessively rainy spells; 135 inches of rain fell in the east end of Jamaica in the eight days, November 4–11, 1909; during the same period another station recorded 96 inches in four days.

The islands enjoy a remarkably uniform temperature, as the monthly means for Kingston show. The thermometer never rises above 100°, or falls below 60°, at sea level. The winters are coolest in the islands nearest the North American continent.

In Mexico we must distinguish the climates of the west coast, the interior plateau, and the east coast. The ordinary local classification by altitude is: tierra caliente from sea level to 3,000 feet, tierra templada up to 7,000 feet, and tierra fria over 7,000 feet (see page 324). Most of the plateau is above 6,000 feet, and is therefore in the upper tierra templada or lower tierra fria zones. The east, being a windward coast, has moist air and, especially in the south, a heavy rainfall, and is clothed with luxuriant tropical forest. The west coast presents a great contrast, for the northern part of it, as well as the adjoining plateau, is largely arid desert, a continuation of the deserts of Arizona, the constant north-west winds giving little rain. This desert region is, in summer, the hottest part of the whole area under consideration.

The north and south sides of the isthmus of Tehuantepec also illustrate the difference in respect of rainfall between windward and leeward coasts, the windward slopes on the north having over 80 inches, the leeward south coast not much more than 40 inches of rain. All the plateau enclosed by the mountain rim of the Sierra Madré suffers from a deficiency of rain, the yearly total being under 10 inches in parts. The mean temperature here is, of course, much lower than on the coasts, but the heat is often greater on summer days; the winter nights are far colder on the plateau, and frost is not unknown at Mexico City, 7,500 feet above the sea. The mean annual range of temperature is nearly the same at Mexico City as at Vera Cruz on the coast.

Central America has a hot, moist, and unhealthy climate. From the annual rainfall map, constructed for the most part from very inadequate data, it appears that most of the region receives more than 80 inches of rain a year. The Panama Canal Zone furnishes the best statistics. There the rainfall exceeds 130 inches on the windward Atlantic coast, and becomes less towards the south, being only 70 inches on the Pacific. The dry season lasts from December to April, but on the Atlantic slope these months are only dry by comparison with the excessive rains that fall during the rest of the year. On the Pacific coast it is a true dry season, with less than 3 inches of rain in the period January to March. The rainiest months are October and November, and May and June. The rains diminish in July. One of the highest monthly means recorded is 23 inches at a station on the Atlantic (Brazos Brook); the driest month here, March, has 3 inches. It will be noticed that there is a close resemblance between this region and the West Indies in the matter of rainfall. Temperature is high and uniform in the Canal Zone, rarely falling below 70° or rising above 90°. The air is moist and the climate unhealthy.

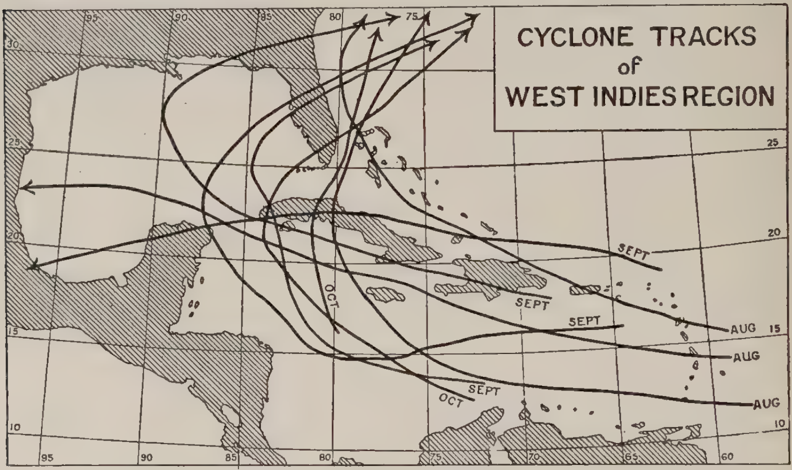


FIG. 135. Some typical Tracks of Hurricanes.

Hurricanes. The climate of the West Indies is a particularly pleasant one for the tropics; but it suffers from one great disadvantage, a liability to hurricanes. These violent tropical cyclones generally originate east of the islands, and sometimes work destruction on one island after another in their westward journey. Some typical tracks are shown in Fig. 135. Not only the West Indies, but also the Gulf coasts of the United States, are within their reach. Even Galveston is not immune; a well-known instance is the hurricane which devastated that town on September 8, 1900.

'The loss of life in the city alone was 3,000, and throughout the whole of Texas it probably exceeded twice that total. Scarcely a house was left standing in the hitherto thriving city, the grain elevators were all overturned, the waterworks a complete wreck, and ships of all sorts were driven on shore. The land is low near Galveston; the water piled up by the storm swept completely over it, and torrential rain added to the distress. Eight ocean-going steamships of considerable tonnage were borne far inland. The *Kendal Castle* was over eight miles inland when the gale took off.' (Pilot Chart.) But most hurricanes recurve towards the north-east, well to the east of the meridian of Galveston. In the 36 years 1876–1911, 143 hurricanes were noted in the West Indies region, distributed as follows:

Jan.	0	Apr.	0	July	5	Oct.	44
Feb.	0	May	1	Aug.	35	Nov.	3
Mar.	0	June	8	Sept.	45	Dec.	2

STATISTICS

MEAN TEMPERATURE (°F.)

SOUTH AMERICA

The West Coast, south of the Equator.

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Callao	coast	68·9	70·2	**70·9**	69·8	66·9	65·5	63·0	*62·4*	62·4	64·2	65·1	68·5	66·6	8·5
Lima	518	71·1	**73·4**	72·9	70·0	66·0	62·1	60·6	*60·6*	61·3	61·9	65·8	69·8	66·2	12·8
Iquique	30	70·7	**70·9**	69·0	64·8	62·7	61·8	*59·5*	61·2	62·5	63·9	66·6	69·4	66·1	11·4
Santiago	1,703	**67·7**	66·8	63·2	56·7	51·7	48·3	*46·9*	48·4	54·5	56·3	61·3	65·2	55·6	20·8
Valdivia	141	**59·5**	58·9	56·6	53·5	51·4	48·5	*46·0*	46·3	49·3	51·1	53·2	56·6	52·6	13·5
Evangelist's Island	174	**47·2**	46·6	46·3	44·8	41·3	39·8	*37·4*	38·6	40·1	41·6	43·0	45·3	42·7	9·8

The Andes Plateau.

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Quito	9,350	54·5	**55·0**	54·5	*54·5*	54·7	55·0	54·9	54·9	**55·0**	54·7	*54·3*	54·7	54·7	0·7
La Paz	12,100	51·6	51·3	50·7	49·1	46·9	*44·1*	44·6	45·9	48·4	50·4	**52·7**	52·2	48·9	8·6
Misti	19,200	**21·4**	21·0	19·8	18·0	15·6	14·0	*13·5*	14·5	16·3	18·7	20·3	21·0	17·8	7·9

South America, north of the Equator.

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Bogota	8,730	*57·6*	57·9	58·6	**58·6**	58·5	58·1	57·2	*57·0*	57·0	57·9	**58·3**	58·1	57·9	1·6
La Guayra	coast	*78·4*	78·4	79·3	80·2	81·1	81·7	81·1	82·6	**82·9**	82·6	81·5	78·8	80·8	4·5
Caracas	3,020	*68·5*	68·9	69·3	72·5	**73·9**	73·0	*72·0*	**72·7**	72·5	71·4	71·2	68·9	71·2	5·4
Georgetown	10	78·4	*78·4*	79·0	**79·5**	79·3	*78·8*	79·0	79·7	81·0	**81·1**	80·4	79·0	79·5	2·7

Brazil, Uruguay, and Paraguay.

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Para	33	77·7	*77·0*	77·5	77·7	**78·4**	78·3	*78·1*	78·3	78·6	79·0	**79·7**	79·0	78·3	2·7
Manaos	148	80·6	80·4	*80·4*	80·4	80·4	80·8	81·1	82·0	82·4	**82·9**	82·6	81·0	81·3	2·5
Pernambuco	98	81·3	**81·5**	80·8	79·9	78·4	76·6	*75·2*	75·7	77·7	79·3	80·4	80·8	79·0	6·3
Rio de Janeiro	197	77·5	**78·1**	77·2	74·1	70·7	68·2	*67·5*	68·7	69·4	71·2	73·4	74·8	72·5	10·6
Cuyaba	738	*79·9*	**80·2**	80·2	79·0	77·2	*73·9*	75·0	76·8	80·8	**80·8**	80·6	80·1	78·8	6·9
São Paulo	2,690	68·9	**69·1**	68·0	64·6	60·4	58·6	*57·9*	59·0	61·5	63·0	65·5	68·0	63·7	11·2
Asuncion	300	80·4	**80·8**	78·8	71·6	66·7	*63·7*	65·3	66·2	69·8	73·2	76·6	80·2	73·0	17·1

SOUTH AMERICA (*continued*)

The Argentine Republic.

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Rosario	95	**76·5**	75·7	70·0	62·4	55·9	*49·3*	51·6	52·3	57·0	62·2	69·4	74·7	63·0	27·2
Buenos Aires	72	**73·6**	73·0	69·6	61·9	55·9	51·1	*50·2*	52·3	57·1	61·0	67·3	71·4	61·9	23·4
Bahia Blanca	49	**70·7**	69·8	66·0	59·4	52·2	45·9	*45·5*	47·3	52·5	57·0	63·3	67·5	58·1	25·2
Santiago	659	**83·3**	81·0	76·6	69·8	64·0	57·9	*57·9*	60·3	68·5	73·4	78·1	81·3	71·1	25·4
Cordoba	1,437	**73·2**	72·5	68·7	61·7	55·6	*49·8*	50·4	53·8	58·8	63·3	68·4	72·1	62·4	23·4
San Juan	2,140	**78·4**	75·9	71·1	61·9	54·1	*47·1*	48·2	50·4	59·0	64·8	70·7	76·3	63·1	31·3
Uspallata	9,335	**53·4**	52·2	50·9	45·9	38·3	*34·3*	35·8	37·8	38·5	41·9	48·2	52·7	44·1	19·1
Santa Cruz	85	**60·6**	57·4	53·6	48·2	40·8	34·2	*33·1*	38·3	43·0	47·8	54·7	55·2	47·3	27·5
Ushuaia	112	**50·0**	48·2	44·6	39·9	33·8	29·7	*28·9*	33·4	38·3	41·9	45·0	46·0	39·9	21·1

Mexico, Central America, and the West Indies.

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Vera Cruz	49	71·4	73·2	74·8	79·0	81·0	81·5	81·7	**81·9**	80·4	76·5	74·8	*70·9*	77·4	11·0
Mazatlan	250	*66·7*	67·3	68·2	71·2	76·1	81·0	**82·2**	81·7	81·7	79·9	74·1	70·0	75·0	15·5
Mexico City	7,474	54·0	56·8	60·4	64·2	**64·9**	63·9	62·4	62·1	61·2	58·6	56·5	*53·4*	59·9	11·5
Guatemala	4,855	*61·3*	62·8	65·7	66·2	**68·0**	66·2	*65·8*	**66·0**	65·7	64·8	62·8	61·3	64·8	6·7
Colon	164	79·5	79·2	79·7	79·9	79·9	79·9	**80·1**	79·3	79·5	79·0	*79·0*	79·5	79·5	1·1
Havana	62	*70·3*	72·0	73·4	76·3	79·2	81·3	**81·9**	81·5	80·4	77·9	74·7	71·6	76·6	11·6
Kingston	49	75·7	*75·7*	76·5	78·3	79·9	81·1	**81·7**	81·0	80·6	79·3	78·6	76·8	78·8	6·0
Bridgetown (Barbados)	56	77·5	*77·0*	77·4	79·0	80·2	80·4	80·1	80·8	**81·1**	80·2	79·5	78·4	79·3	4·1

MEAN RAINFALL (inches)

SOUTH AMERICA

Station.	Alt. Feet.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
The West Coast, south of the Equator.														
Lima	522	0·03	0	*0*	0·03	0·03	0·2	0·3	**0·5**	0·5	0·1	0·03	0·03	1·8
Arequipa	7,740	0·6	**3·2**	0·5	0	0	0	*0*	0	0	0	0·1	0	4·4
Iquique	30	0	*0*	0	0	0	0	0·02	0	**0·03**	0	0	0	0·05
La Serena	33	*0*	0	0·1	0	**1·3**	1·2	1·1	0·4	0·1	0·1	0	0	4·3
Valparaiso	135	*0*	0	0·9	0·1	2·7	**6·0**	5·3	3·4	0·4	0·5	0·3	0	19·6
Santiago	1,703	*0*	0·1	0·2	0·6	2·3	3·2	**3·4**	2·4	1·2	0·6	0·2	0·2	14·4
Valdivia	49	*2·9*	3·2	6·4	9·3	15·3	**17·5**	15·4	13·5	7·3	5·0	4·4	4·8	105·0
Evangelist's Island	174	**12·8**	8·9	12·3	11·6	8·8	8·5	8·9	8·6	*7·7*	9·0	10·3	9·6	117·0
The Andes Plateau.														
Quito	9,350	*3·2*	3·9	4·8	**7·0**	4·6	1·5	*1·1*	2·2	2·6	3·9	**4·0**	3·6	42·3
La Paz	12,110	*3·9*	**4·5**	2·6	1·5	0·5	*0·1*	0·2	1·1	0·8	1·3	1·5	**4·3**	21·2
Sucre	9,190	**6·5**	4·8	3·6	2·0	0·2	0·2	*0·2*	0·2	0·9	1·3	2·7	4·6	27·2
South America, north of the Equator.														
Bogota	8,730	3·7	*3·5*	4·5	**9·6**	6·5	3·2	*2·6*	3·3	2·9	8·4	**9·6**	5·6	63·4
Cartagena	coast	0	*0*	0·1	0·1	4·3	**5·3**	*3·2*	5·3	5·3	**8·8**	4·6	0·6	37·6
Caracas	3,050	0·9	*0·3*	0·6	1·2	2·8	4·0	**4·8**	*3·8*	4·2	**4·4**	3·3	1·6	31·9
Georgetown	10	7·6	5·7	*5·7*	6·5	10·9	**12·0**	9·7	6·7	2·7	*2·4*	5·7	**11·3**	86·9
Cayenne	20	**14·1**	*12·1*	15·2	15·5	**20·0**	14·8	6·5	2·6	*1·1*	1·3	4·6	10·6	118·4

SOUTH AMERICA (*continued*)

Brazil, Uruguay, and Paraguay.

	Alt. Feet.	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Para	33	10·3	12·6	**13·3**	13·2	9·3	5·7	4·9	4·3	3·2	2·5	*2·3*	5·1	86·7
Manaos	150	8·3	8·0	8·1	**8·4**	6·6	3·9	1·8	*1·3*	2·2	4·6	4·5	8·2	65·9
Iquitos	328	10·2	*9·8*	**12·2**	6·5	10·0	7·4	6·6	*4·6*	8·7	7·2	8·4	**11·5**	103·1
Ceara	66	3·2	7·1	11·7	**13·4**	9·3	4·7	2·2	1·1	0·6	*0·5*	0·5	1·5	55·8
Pernambuco	10	3·0	3·4	6·9	10·8	12·5	13·9	**14·0**	7·7	3·4	1·1	*0·9*	1·3	78·9
Sta. Anna do Sobradinho	1,053	3·0	1·6	5·8	0·4	0·2	0·3	*0*	0	0·5	1·5	0·4	0·9	14·6
Ouro Preto	3,750	**16·6**	15·0	10·8	4·1	1·8	0·9	*0·9*	**1·6**	3·3	5·0	9·3	10·2	79·5
Rio de Janeiro	216	5·0	*4·3*	**5·3**	4·4	3·5	2·0	*1·6*	1·8	2·6	3·2	4·3	**5·4**	43·4
Santos	10	10·6	8·5	**11·9**	6·7	6·2	*2·4*	4·5	4·6	5·5	**6·2**	**7·7**	7·1	82·1
São Paulo	2,690	8·0	8·1	5·7	2·2	2·6	2·1	*2·0*	2·0	3·5	4·8	7·1	**8·7**	56·3
Campinas	2,224	**9·5**	8·1	5·9	2·4	2·4	1·9	*1·1*	1·4	2·9	4·8	**6·3**	8·4	55·0
Rio Grande do Sul	56	2·6	2·8	3·0	**3·4**	2·7	*2·3*	4·4	**4·4**	4·4	3·0	*2·1*	2·2	37·3
Monte Video	26	3·2	*2·4*	3·5	3·4	**3·9**	3·3	3·3	*2·7*	3·1	**3·7**	3·0	3·1	38·5
Estancia Concordia	—	4·3	*2·4*	**4·9**	3·6	3·0	*2·6*	2·9	3·2	3·7	3·4	3·1	**4·8**	41·9
Asuncion	300	**6·7**	5·7	5·2	5·1	4·0	2·6	2·2	*1·9*	3·1	5·4	6·1	6·1	54·1

The Argentine Republic.

	Alt. Feet.	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Corrientes	256	**5·7**	4·9	5·3	5·3	3·5	3·2	1·6	*1·6*	2·7	4·6	5·1	4·8	48·3
Santa Fé	66	*3·3*	3·5	**5·1**	3·3	1·8	*0·9*	1·0	0·9	1·9	3·4	3·4	**4·6**	33·0
Rosario	95	3·7	*3·2*	**5·3**	3·1	1·8	1·5	*1·0*	1·5	1·6	3·5	3·4	**5·3**	34·9
Buenos Aires	72	3·0	*2·5*	**4·6**	3·0	2·8	2·7	*2·2*	2·4	3·0	3·6	2·8	**3·9**	36·5
Azul	453	3·0	*2·4*	**4·5**	2·2	1·9	*1·6*	1·9	2·2	1·9	3·2	**3·2**	3·1	31·1
Bahia Blanca	49	*1·7*	2·1	**2·7**	2·1	1·2	1·1	*1·0*	1·1	1·5	2·2	**2·2**	1·9	20·8
Santiago	659	*2·8*	3·2	**4·6**	1·6	0·6	0·2	0·2	*0·1*	0·6	1·5	2·1	**3·3**	20·8
Cordoba	1,437	4·4	4·3	3·7	1·6	0·8	0·3	*0·2*	0·4	0·8	2·4	4·3	**4·7**	27·9
San Luis	2,490	3·3	3·0	2·4	1·0	0·6	*0·2*	0·3	0·4	0·6	2·3	3·5	**3·6**	21·2
Salta	3,940	**5·4**	4·6	3·9	1·1	0·2	0	*0*	0·1	0·3	0·6	2·4	3·8	22·4
La Rioja	1,230	**3·1**	1·9	1·5	0·4	0·1	*0·1*	0·2	0·1	0·1	0·8	1·3	1·9	11·3
San Juan	2,140	**0·7**	0·3	0·3	0·1	0·1	0	*0*	0	0·1	0·3	0·2	0·4	2·5
Uspallata	9,335	0·8	1·2	0·2	*0*	0·1	0·6	0	1·6	0·2	**1·3**	0·8	0·2	7·0
Santa Cruz	85	0·5	0·3	*0·2*	0·6	0·7	0·4	**1·1**	0·4	*0·2*	0·4	0·4	**1·0**	6·0
Punta Arenas (Chile)	56	1·2	1·5	**1·9**	1·7	*1·6*	**2·0**	2·0	1·4	*1·1*	1·3	1·2	1·5	18·2
Ushuaia	112	1·8	**2·5**	2·3	1·5	1·3	2·3	1·4	*0·9*	1·5	1·7	2·0	2·3	21·5

MEAN RAINFALL (inches), *continued*

Mexico, Central America, and the West Indies.

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Vera Cruz	49	0·4	0·6	0·6	*0·1*	4·3	12·5	**14·8**	*8·9*	**11·6**	9·0	3·2	2·0	68·0
Chichuahua	4,690	*0*	0·7	0·4	0·1	0·3	1·4	**8·1**	5·9	5·1	1·3	0·8	0·1	24·2
Mexico City	7,474	*0·2*	0·2	0·6	0·6	1·9	3·9	4·1	**4·7**	4·1	1·8	0·5	0·2	23·1
Guatemala	4,855	0·3	*0·2*	0·5	1·3	5·6	**11·5**	8·0	*8·0*	**9·2**	6·7	0·9	0·2	52·4
Panama (District)	coast	0·7	*0*	0·7	1·9	**6·9**	6·5	6·5	*5·7*	7·3	**8·2**	8·0	4·0	56·4
Balboa (Canal Zone, Pacific)	coast	1·1	*0·7*	0·7	3·9	8·5	7·4	8·2	7·9	6·8	**9·6**	9·1	5·8	69·7
Culebra (Canal Zone, Interior)	—	1·6	0·7	*0·6*	3·6	11·1	8·8	9·3	10·3	10·7	11·5	**12·3**	7·2	87·7
Colon (Canal Zone, Atlantic)	coast	3·9	*1·7*	1·7	4·2	12·6	13·5	16·2	14·9	12·5	14·8	**21·5**	11·9	129·4
Havana	66	2·7	2·3	*1·8*	2·8	4·5	**7·2**	*5·0*	6·0	6·7	**7·4**	3·1	2·2	51·7
Kingston	60	1·0	*0·7*	1·0	1·0	**4·6**	4·4	*1·8*	3·9	4·2	**8·1**	3·0	1·8	35·6
Port Antonio (Jamaica)	10	9·1	6·2	*4·9*	6·3	16·7	**18·0**	11·6	10·8	*10·4*	15·2	**16·4**	13·8	139·2
Fort de France (Martinique)	13	4·7	4·3	*2·9*	3·9	4·7	7·4	9·4	**10·3**	9·3	9·8	7·9	5·9	80·5

PART VII

AUSTRALIA AND NEW ZEALAND

CHAPTER XLIII

GENERAL FEATURES

The possibilities of the future development of Australia, which is the most arid of the continents, depend largely on the vital question of rainfall. Hence, in describing the general features of position and relief, we shall naturally lay chief stress on those circumstances to which the scantiness of the rainfall may be attributed.

Australia lies in one of the driest belts of the earth, the calms of the subtropical high pressures, and the trade winds which blow out from them towards the Equator. The continent, excluding Tasmania, lies between latitudes 11° S. and 39° S. The tropic of Capricorn crosses it near the middle. There is a close resemblance to North Africa where the same latitudes of the north hemisphere include the Sahara. In South Africa also the parallels which bound Australia enclose the arid section which includes the Kalahari and the coastal desert of South-west Africa. 37 per cent. of the area of Australia has less than 10 inches of rain a year, only 7 per cent. more than 40 inches.

The interior of a continent naturally tends to have a poor rainfall owing to distance from the sea, the ultimate source of moisture. In this respect Australia has the advantage of being the smallest of the continents, and of being insular. But, on the other hand, the land mass is compact, the only great indentation in the coastline being the Gulf of Carpentaria; the advantages conferred on Europe by her long coastline are conspicuously absent in Australia. There are no great lakes as in North America, only a few shallow salt-pans, usually dry when water is most needed in time of drought; no river Amazon helps to provide rain in the interior by evaporation from its surface. The

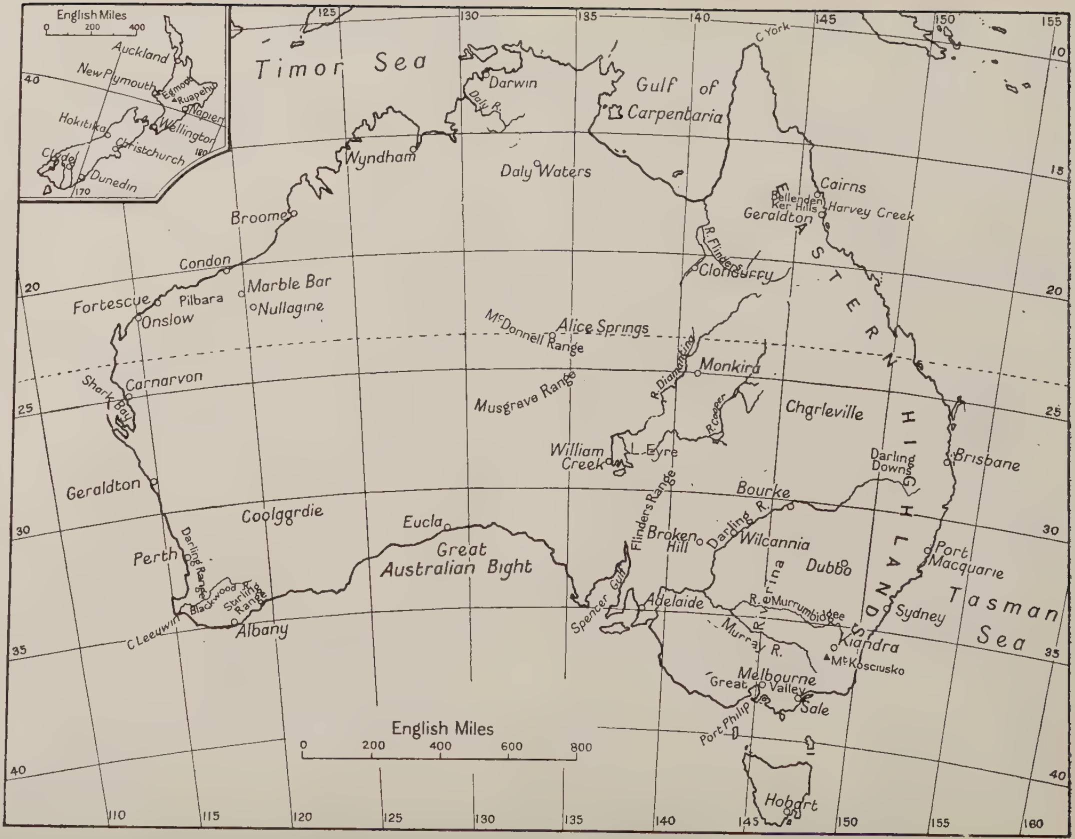

English Miles
0
200
400
Auckland
New Plymouth
Egmont
Ruapehu
Napier
Wellington
Hokitika
Christchurch
Clyde
Dunedin
40
170
180
Timor Sea
Darwin
Daly R.
Gulf of Carpentaria
C York
Wyndham
Daly Waters
Cairns
Bellenden Ker Hills
Harvey Creek
Geraldton
Broome
Condon
Marble Bar
Nullagine
Pilbara
Fortescue
Onslow
R. Flinders
Cloncurry
EASTERN HIGHLANDS
McDonnell Range
Alice Springs
R. Diamantina
Monkira
Carnarvon
Shark Bay
Musgrave Range
R. Cooper
Charleville
William Creek
L. Eyre
Darling Downs
Brisbane
Geraldton
Flinders Range
Bourke
Darling R.
Coolgardie
Eucla
Broken Hill
Wilcannia
Dubbo
Riverina
Perth
Darling Range
Blackwood R.
Stirling Range
Great Australian Bight
Spencer Gulf
Adelaide
R. Murrumbidgee
Port Macquarie
Sydney
Tasman Sea
C Leeuwin
Albany
Murray R.
Kiandra
Mt Kosciusko
Melbourne
Great Valley
Sale
Port Phillip
English Miles
0
200
400
600
800
Hobart
110
115
120
125
130
135
140
145
150
155
160
10
15
20
25
30
35
40

Fig. 136. Key map, showing the position of places named in the text.

continent is placed with its greatest length from east to west, as if to ensure that the maximum possible area should be subject to the most arid conditions.

Except in the east, the relief is not favourable to heavy rainfall. The western half of the continent is a plateau between 600 and 1,500 feet above the sea, on which rise various small isolated ranges, such as the MacDonnell and Musgrave Ranges, which exceed 3,000 feet. The south-western rim of the plateau also rises above the general level in the Darling, Blackwood, and Stirling Ranges. All these heights, especially those in the south-west, cause a local increase in rainfall. The lowest part of the continent is the region between the Gulf of Carpentaria and Spencer Gulf, most of which is below 500 feet, while the Lake Eyre district is actually below the level of the sea, Lake Eyre itself being 39 feet below. Much of Victoria and New South Wales in the basins of the Darling and Murray must be included in the lowlands, being less than 500 feet above the sea. The eastern Highlands are the only extensive mountain system in Australia. They start in the Cape York Peninsula, and for the most part do not greatly exceed 2,000 feet in height in Queensland, though small areas are much higher; the Bellenden Ker Hills reach 5,000 feet, and are the rainiest part of the continent. In New South Wales the general altitude is greater, exceeding 3,000 feet, and the Australian Alps in the south-east of the state attain 7,320 feet in Mount Kosciusko, the highest point in Australia, and the only part which bears snow all the year. The average height of the Range in Victoria is about 3,000 feet.

A coastal plain, only slightly above sea level, surrounds the continent. It is very narrow, 20 miles or less, in parts, but in some places it widens to 100 miles.

The influence of the relief on the climate is evident. The lowest region, the Lake Eyre depression, is the most arid, and has less than 5 inches of rain a year. The eastern Highlands are the most rainy; in Queensland they are high enough to cause the south-east trades, normally dry winds, to give abundant rain, and in New South Wales even anticyclonic winds which rise over the range from seaward are rainy.

Oceanic conditions. The north and east coasts are washed by the warm waters brought across the South Pacific Ocean by the south equatorial current. Part of the current makes its way westward, filling the shallow seas and straits north of Australia, where the highest mean annual sea-temperature of the globe is found; part branches southward and becomes the East Australian current, which flows past Queensland and New South Wales. On the south and west of Australia we find the cool water of the Antarctic Drift. The west coasts of South Africa and South America in the same latitudes are remarkable for the cold water which partly is brought by the Antarctic Drift, partly wells up from the depths under the influence of the trade winds sweeping away the surface water. No doubt there is a tendency to the same conditions off west Australia, but, owing to the shorter extent of north–south coastline, and to its convex shape, the upwelling seems to be inappreciable, and the striking contrasts in temperature between the east and west coasts of the other southern continents are not found in Australia; indeed Perth is somewhat warmer than Sydney during most of the year. And as regards rainfall, which largely depends on the temperature of the sea-water, hardly any of the west coast of Australia is true desert, while hundreds of miles of the west coasts of the other continents are almost rainless.

CHAPTER XLIV

AUSTRALIA: TEMPERATURE

In summer the warmest region is the Pilbarra district in the north-west, where the sun is overhead and there is little cloud; a considerable area is enclosed by the 90° isotherm in December. Almost all the continent north of the tropic has a mean temperature above 80°. The interior is warmer than the coasts, and it is noticeable that the west coast is considerably warmer than the east, in spite of the cool current which flows past it. It becomes cooler towards the south, the isotherms having a general east–west direction, but tending to run parallel to the south coast, and making a bend northward as they approach the east coast of the continent; there is a similar but much smaller bend towards the north in the neighbourhood of the west coast. The 65° isotherm skirts the coast of Victoria.

The 90° isotherm (Fig. 137) continues to encircle the Pilbarra district in January, February, and March. The east coast of the continent is cooler than the west in all these months, and the mean temperature on the Queensland coast is as high as 80° only in January. In April there is a marked drop in temperature everywhere; the 85° isotherm encloses Pilbarra, and the 55° isotherm is appearing over Victoria. July is the coolest month; the north-west coast is the warmest part of the continent with a mean temperature just over 75°, Victoria and the south of New South Wales coolest, with a temperature below 50°; the west coast of the continent is warmer than the east, as in summer.

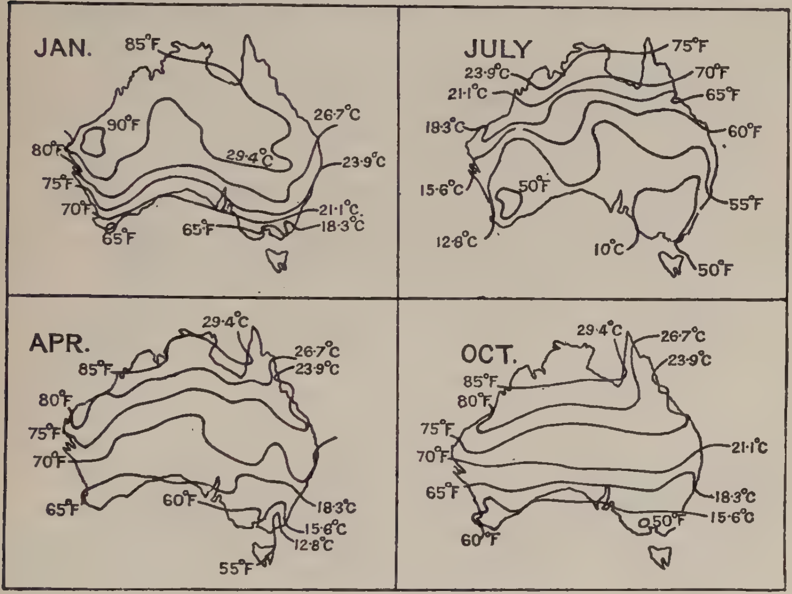

JAN.
85°F
90°F
80°F
75°F
70°F
65°F
65°F
26·7°C
29·4°C
23·9°C
21·1°C.
18·3°C
JULY
75°F
70°F
65°F
60°F
55°F
50°F
23·9°C
21·1°C
18·3°C
15·6°C
50°F
12·8°C
10°C
APR.
29·4°C
26·7°C
23·9°C
85°F
80°F
75°F
70°F
65°F
60°F
18·3°C
15·6°C
12·8°C
55°F
OCT.
29·4°C
26·7°C
23·9°C
85°F
80°F
75°F
70°F
65°F
60°F
21·1°C
18·3°C
15·6°C
50°F

Fig. 137. Mean Temperature.

Not only the highest mean temperatures but also the highest midday readings are recorded in the west and centre of the continent, a short distance inside the tropic, as in Africa. According to the Commonwealth meteorologists the maximum shade temperature has been known to exceed 100° over a wide area on 64 consecutive days. Marble Bar, Pilbarra, appears to have the most persistent heat, for a maximum of 90° or over has been recorded on 151 consecutive days (Fig. 138). The heat is evidently not much less than in the hottest parts of the Sahara. Exceedingly high temperatures occur everywhere in the interior near the tropic, where the cloudless sky and dry air give free passage to the sun's rays, which are most powerful during the southern summer when the earth is nearest to the sun. Stuart recorded 131°, and says the sand was so hot that matches burst into flame when dropped on to it. Alice Springs, situated almost on the tropic, 2,000 feet above the sea, records 115° in most years. Intense heat is sometimes experienced far south, even on the south coast; the thermometer at Bourke has touched 121°, at Adelaide 116°, at Melbourne 111°. The heavy rain and thick clouds of the summer monsoon preclude such high temperatures in the north as are experienced in parts of the continent much farther from the Equator. The warmest month at Darwin is November, with a mean temperature of 84°; the highest temperature recorded in most years does not much exceed 100°. But these lower latitudes of Australia are much warmer than the rest of the continent in winter, the July mean at Darwin being 75° and the thermometer rarely falling below 60°.

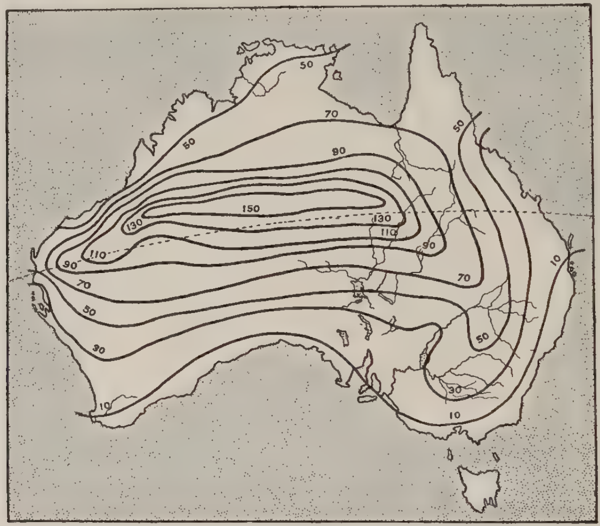


Fig. 138. Lines showing the number of consecutive days on which the air temperature has exceeded 90°.

Australia labours under many disabilities owing to her arid climate, but in one respect at any rate the dry air is an advantage, inasmuch as it tempers the summer heat by promoting rapid evaporation, and so lowering the 'physiological' temperature, that is to say, the actual heat felt by man. It has often been pointed out that the wet-bulb thermometer is a better indication of the conditions as affecting mankind than the ordinary dry-bulb. The average wet-bulb readings at Pilbarra are some 20° lower than the dry-bulb, the mean for the summer months being only about 75°. Along the tropic the mean summer wet-bulb temperature is about 70°. At Melbourne the wet-bulb very rarely exceeds 75° even on the hottest days.

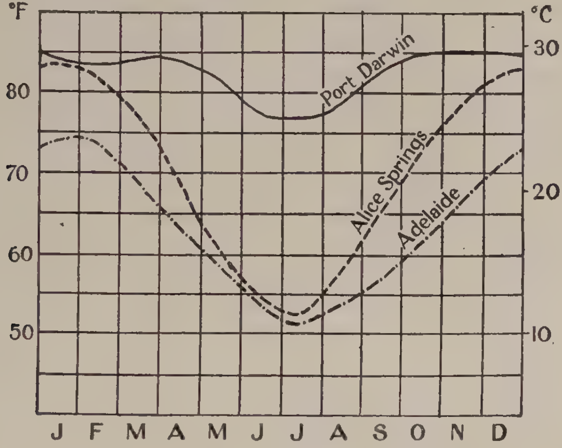


FIG. 139. Curves showing mean monthly temperature. Alice Springs (lat. 24°) is as warm as Darwin (lat. 12°) in summer, but much colder in winter. Adelaide (lat. 35°) has almost the same mean as Alice Springs in winter, but is cooler in summer.

The relative humidity of the air is much lower in most parts in summer than in winter, although summer is the rainy season. In the extreme north, however, the air is much drier in winter, since the effect of the higher temperature in summer is more than neutralized by the moist air of the monsoon.

The temperature may fall below freezing-point on winter nights everywhere south of the tropic, since the clear dry air, which is so transparent to the rays of the sun by day, is but a feeble protection against loss of heat by radiation at night. Even in summer the nights are cold in the desert, and in most winters the thermometer falls as low as 25° at Alice Springs. The winters in the interior are pleasant, and travellers naturally choose that season for their journeys if possible, since the brisk dry south-east wind makes even the hottest hours of the day bearable. We often find the statement in journals of travel that water-bottles which had been left outside the tent all night were found frozen solid on winter mornings.

On the south coast, though the mean temperature is lower, the nights are less cold owing to the influence of the sea. At Adelaide the thermometer has fallen to freezing-point, but not below it; at Melbourne to 27°. Snow falls occasionally even near sea level south of lat. 31° S., and on the mountains as far north as the south of Queensland. It is heaviest around Mount Kosciusko, where it lies in patches throughout the year; Kiandra, 4,640 feet above the sea, in this neighbourhood, has recorded a temperature of −8°.

From these facts it follows that the range of temperature depends as much on distance from the sea as on latitude. The mean annual range at Darwin is only 8°, since the station is on the sea coast and in a low latitude; at Adelaide it is 23°, and at Alice Springs 32° (Fig. 139). The daily range is greater than might be expected, owing probably to the dryness of the air:

MEAN DAILY RANGE OF TEMPERATURE

	Month with greatest range.	*Month with least range.*
Melbourne	21 (Jan.)	13 (June)
Adelaide	25 ,,	14 ,,
Brisbane	21 (Aug.)	16 (Feb.)

The daily range is, of course, much greater in the arid interior.

Comparing Australia with Europe in respect of temperature, we find that Melbourne resembles Oporto fairly closely. Perth, which is representative of the Mediterranean climate region of Australia, has summers not unlike those of the Riviera, but much warmer winters. Hobart is similar to Penzance.

The hot waves and cold waves, which are an important feature of the south and east of Australia, will be described later.

CHAPTER XLV

AUSTRALIA: PRESSURE AND WINDS

THE central feature in the meteorology of Australia is the high-pressure ridge, which appears on the mean isobar map of every month of the year, being part of the subtropical high-pressure belt of the southern hemisphere. We can best appreciate its significance from the point of view of the daily weather. The high-pressure belt of our isobar maps really represents a region which is traversed by an almost constant procession of anticyclones, moving from west to east at an average speed of about 17 miles an hour. We may contrast the low-pressure area to the north-west of Europe, which is a region where cyclone follows cyclone with little interruption. The anticyclones usually enter Australia as more or less circular systems, but their north–south axis widens as they cross the continent; this widening is seen in the mean isobars which enclose the high-pressure area. Now an anticyclone is, speaking generally, a system of descending air currents. As the air descends it becomes compressed and, therefore, warmer and drier, with the result that the sky is cloudless and there is no rain, so that a country which is mainly under anticyclonic influence must have an arid climate. The winds blow out, and are deflected to the left hand like all other free movements in the southern hemisphere of the rotating earth, so that they appear as south-east winds (trade winds) on the equator-ward side of the high-pressure belt; and here they have the usual trade-wind characteristic of dryness, caused both by their origin and by the fact that they are constantly reaching warmer latitudes, so that their vapour-capacity is increasing. On the poleward side the prevailing out-blowing winds are north-westerly, and they also are dry as long as they are within the anticyclonic area, but they are ready to provide rain when they enter the cyclonic belt of the Roaring Forties.

Between each pair of anticyclones there must be some arrangement of lower pressure, just as there are higher pressures between the successive cyclones of North-west Europe. But there is rarely a fully-developed cyclone between the anticyclones of Australia.

The lower pressures are usually merely in the form of a 'col'; that is to say, there is a continuous ridge of high pressure, on which the separate anticyclones form isolated 'summits' of still higher pressure (Fig. 140). Rain in any quantity is rare in a col, and we must especially notice that since the high-pressure ridge remains even in the col, the north and south of the continent are meteorologically isolated from each other, and the winds which start in the high pressures in the centre of the land mass can contain little moisture. But sometimes the ridge is completely broken down between two anticyclones, which are separated by a pronounced depression connecting the low pressures over the north and the south of the continent (Fig. 140). The word 'trough' is applied to this formation by the Commonwealth meteorologists, who lay great stress on the essential difference between it and the col, both as definite pressure formations, and in their controls of the rainfall of much of the continent. They compare the 'col' to the mountain feature from which the name is derived, that is a saddle in a ridge, between the mountain massifs on each side, while a 'trough' is a river valley cutting through the ridge and so effecting a complete separation of the massifs. The col is essentially an anticyclonic formation, preventing any passage of air from north to south, through the baric ridge. But, just as a valley permits the passage of the river from one side of a ridge to the other, so a trough allows air currents to sweep right across the continent, and it is during the passage of a trough that the interior of Australia, a region of scant and uncertain precipitation, sometimes receives good and general rains, the rain falling in the belt extending from north to south in the front of the trough.

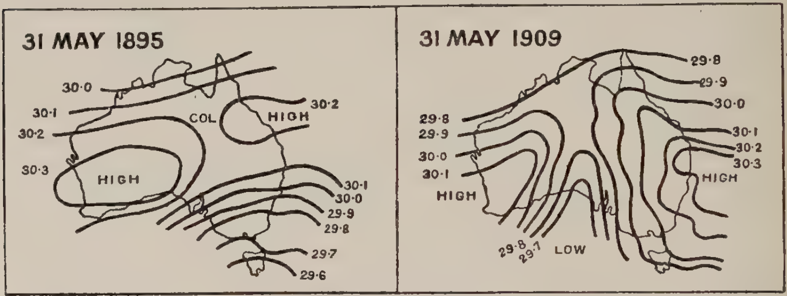


FIG. 140. Showing a 'col' on May 31, 1895, and a 'trough' on May 31, 1909

We must now consider the seasonal migration of the high-pressure belt, that is to say, of the path of the procession of anticyclones. The mean isobar maps (Fig. 141) show that the belt is farthest north during the southern winter, owing partly to the northward swing of the pressure belts with the sun, partly to the intensification of the high pressures in the dry cool air over the land mass. In the July map the 30·1 inch isobar encloses most of the continent south of the tropic, the highest pressures being along lat. 30° S. To the north there is a steady and uniform decrease of pressure, and the prevailing winds are the south-east trades. This is the dry season over the whole continent north of the tropic, and, except in the east, the sky is almost cloudless. The trades are rarely interrupted by disturbances, since the centre of low pressure is far away, over north India, where the summer monsoon is now blowing. On the south side of the baric ridge the gradient is southward and the prevailing winds are north-west, but the conditions are much more disturbed and irregular from day to day than in the north. The southward gradient leads to the low-pressure belt in the neighbourhood of the Antarctic Circle. Here in the Roaring Forties cyclone follows cyclone throughout the year and the weather is stormy, rainy, and mild. These Antarctic depressions control the weather of the south-west of West Australia, the south of South Australia, all Victoria, and the south of New South Wales. As a rule, the main depressions pass from west to east, well out to sea, and only the extreme south of the continent derives some benefit from the rainy northern sectors. But often secondary V-shaped extensions, with the point towards the north, project from the

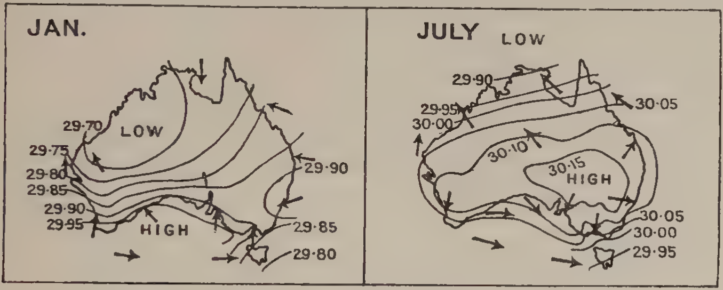


Fig. 141. Mean Pressure and prevailing winds.

primary depression even beyond the tropic, between anticyclones of the high-pressure belt. When a cyclone makes its way farther north than usual, so that its centre passes over Victoria, the weather there is unusually boisterous and wet, and the south coast is swept by cold polar winds.

In summer, pressure is lower everywhere. The high-pressure belt is much diminished in width and intensity, and, having swung south with the sun, lies over and south of the south coasts. The Antarctic cyclones are kept well to the south, and rarely extend their influence so far north as to give Australia any rain; Victoria, being farthest south, is most liable to be affected, but even here the rainfall is much less than in winter. The rest of the south coast enjoys rainless weather with abundant sunshine. The north of Australia is having its rainy season. Just as the hot land-surface of Asia develops a deep low-pressure system in July, so in January a closed depression lies over the north-west of Australia; Pilbarra, the hottest region, has the lowest pressure. This is the scene of numerous shallow, slowly-moving, cyclones. The wind, usually light in force, blows in from all sides, and there is heavy rain in the north of the continent, where the air is saturated with moisture after crossing the hot seas between Asia and Australia. But on the west side of the low-pressure system, the winds are from the south-east, and as they have come over the land from the high pressures on the south they are dry, and give little rain.

CHAPTER XLVI

AUSTRALIA: RAINFALL

Australia falls naturally into three main rainfall provinces, the north, the south, and the interior, conditioned directly by the distribution of pressure (Fig. 142). The north receives its rain in summer, when the high pressures have retreated far to the south, leaving the way open for the monsoon (Figs. 143 and 144). The south has rain in winter, when the high-pressure belt is over the interior, and Antarctic cyclones reach the coast (Fig. 145). The interior is dry in all seasons, since neither the monsoon rains of summer nor the cyclonic rains of winter reach it in strength; this arid tract, with less than 10 inches of rain a year, is of vast extent, no less than 1,045,000 square miles, more than one-third of the whole continent. The boundaries of the summer and winter rainfall provinces are shown in Fig. 142; the region between them is arid in the west and centre, and in the east gets rain in all seasons (Fig. 146). A fourth rainfall province (Fig. 147), which includes the east coast and the adjacent highlands, owes its existence to the relief; parts of it have the heaviest rainfall of the continent. On the Queensland coast, east and south-east winds, which are for the most part true trade winds, prevail all the year. The trades are, by their nature, dry winds, but here they blow from a warm sea, and in rising over the Eastern Highlands they are cooled below dew-point and give copious rain. The coast of New South Wales has variable winds, since it lies in the track of the anticyclones, which pass over it in all seasons as they leave the continent; much of the rainfall may be described as anticyclonic, since it is caused

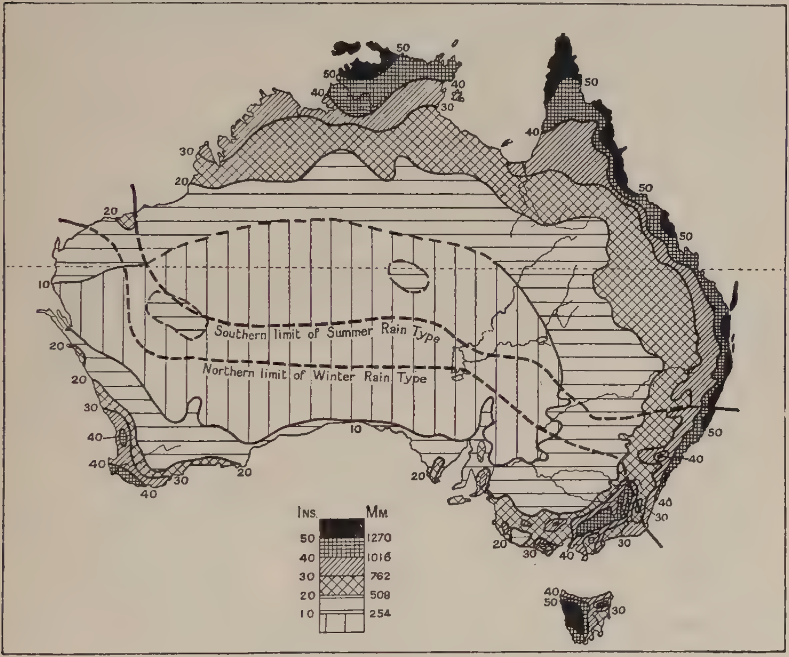

Southern limit of Summer Rain Type
Northern limit of Winter Rain Type
INS.
MM
50 1270
40 1016
30 762
20 508
10 254
50
40
30
20
10

FIG. 142. Mean annual Rainfall.

by the ascent of east winds blowing out from anticyclones over the Tasman Sea, but saturated with moisture by their passage over the warm water. The west coast of Australia is not so favourably situated. Numerous anticyclones cross it as they do the east coast, but the south-west winds in front of them come from a cool sea to a warm land, and there is no elevation sufficient to cause much precipitation; the north-east winds which blow out in rear of anticyclones which have crossed the coast are even more ineffective, since they blow from the land. It might seem likely that the west coast about the tropic would derive considerable rain in summer from the monsoonal low-pressure systems of the north of the continent, but, as we have seen, the prevailing winds here are the dry south-east trades. In winter the rainy influence of the Antarctic cyclones is appreciable almost to Shark Bay; but between here and the tropic there is very little rain in any season, and the arid tract, with less than 10 inches of rain, which covers so much of the interior, reaches the coast.

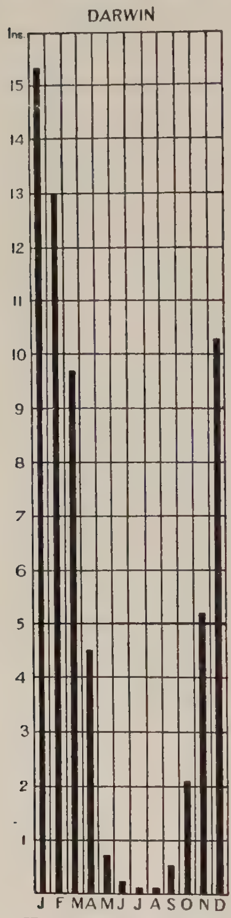


Fig. 143. Mean Rainfall at Darwin, typical of the region with a pronounced summer maximum.

The rainy area of Australia in the different seasons (Fig. 148) has been aptly likened by the authors of *Climate and Weather of Australia* to a crescent, which lies over the north-west, north, and east coasts in summer, the north-east, east, and south-east in April, the south-east, south, and south-west in July, and in October has swung back so that it covers the east coast with its tips over the south and north. Thus it covers the east coast all the year, the north coast mainly in summer, and the south coast mainly in winter; but the west is never within its influence. The rainfall of Australia is essentially peripheral.

The summer-rain region has two well-marked seasons, the wet and the dry. The dry season continues almost rainless till the end of September. Then, as the heat increases, the south-east trades become less constant. Thunderstorms begin early in October, and they become more frequent and violent till, in November, the monsoon sets in more or less steadily from north-west, interrupted at times by calms. The sky is overcast with heavy clouds, and rain falls almost every day. The air is saturated with moisture, and therefore the heat, though it is less intense than just before the monsoon, is harder to bear. The rains continue till the end of April, when the south-east winds appear again. The rainfall is greatest, over 60 inches, on the north coast round Darwin, and it decreases southward, the 10-inch isohyet passing near Alice Springs.

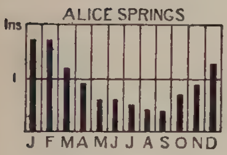


Fig. 144. Mean Rainfall at Alice Springs. The summer maximum is clearly marked, but the total rainfall is scanty.

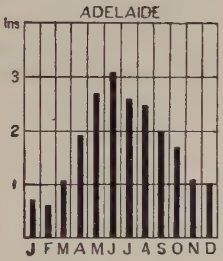


Fig. 145. Mean Rainfall at Adelaide, typical of the region with a pronounced winter maximum.

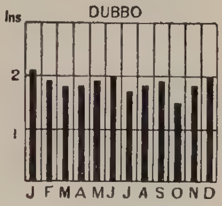


Fig. 146. Mean Rainfall at Dubbo, typical of the region with rain in all seasons.

The Queensland coast has rain all the year, most in summer and autumn, least in spring. The rainfall is greatest near the coast itself, which has about 50 inches in the south of the State; around Geraldton, in the Bellenden Ker Hills, the annual total amounts to 140 inches. There is a rapid decrease towards the west, to only 30 inches south-east of the Gulf of Carpentaria. New South Wales also has heavy coastal rains, well distributed over the year. At Sydney there is most rain in autumn. All the east coast of Australia is liable to exceedingly heavy downpours; at Harvey Creek 255 inches is the heaviest total, 80 inches the lightest, recorded in a year; many stations both on the coast and on the hills have recorded more than 20 inches in a day. The hills overlooking Brisbane have had 105 inches in 12 days. At such times rivers have been known to rise in flood 80 feet above the ordinary level.

In Victoria, the heaviest rainfall is not on the coast but on the hills. The annual amount exceeds 50 inches both on the Highlands of the interior, and on the hills which rise on both sides of Port Philip and bound the Great Valley on the south. The Great Valley itself has less than 25 inches at its east end. In Victoria, as in New South Wales, the rain is well distributed over the year, but here winter is the rainiest season.

Crossing the Eastern Highlands towards the interior, we soon reach the 30-inch isohyet, which follows the 2,000 feet contour line in much of New South Wales and Victoria. The Darling Downs have a pleasantly dry and cool climate, with from 20 to 30 inches of rain. It is important to notice that only a little more than 40 per cent. of Queensland and Victoria has more than 20 inches of rain, and about 17 per cent. has less than 10 inches. Unfortunately the rainfall is not only scanty but also uncertain, and serious droughts are only too common everywhere inside the Highlands. Victoria is the only state which has a mean rainfall of more than 10 inches everywhere, the 10-inch isohyet passing just outside its north-west corner. But northern Victoria often shares the long droughts of the Riverina.

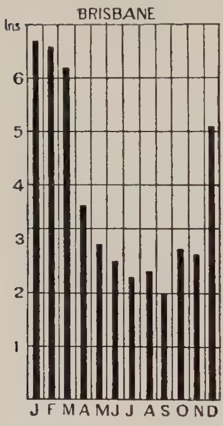


FIG. 147. Mean Rainfall at Brisbane, coast of Queensland.

In South Australia, the mountains have a good rainfall, and the 10-inch isohyet is thrust far north by the Flinders Range. The seaward end of the range, near Adelaide, has over 40 inches, Adelaide itself 21 inches a year. South Australia has a smaller proportion of its area with adequate rainfall than any other state, only 16 per cent. receiving more than 10 inches. The region round Lake Eyre, with less than 5 inches, is the driest part of the continent.

The shores of the Bight are arid, the 10-inch isohyet skirting the shore, but in the south-west of West Australia, we reach better conditions. The Darling Range and other elevated parts of the edge of the plateau face the cyclonic winds of winter, and a considerable area has more than 20 inches of rain. There is more than 40 inches round Cape Leeuwin; Perth has 33 inches.

The Spencer Gulf district and the south-west corner of West Australia form Australia's 'Mediterranean' climate province. Owing probably to the dry air and bright sunshine, wheat flourishes remarkably well, and commands the highest prices in the world's markets. The olive, and other characteristic trees of the south of Europe, have been introduced with success.

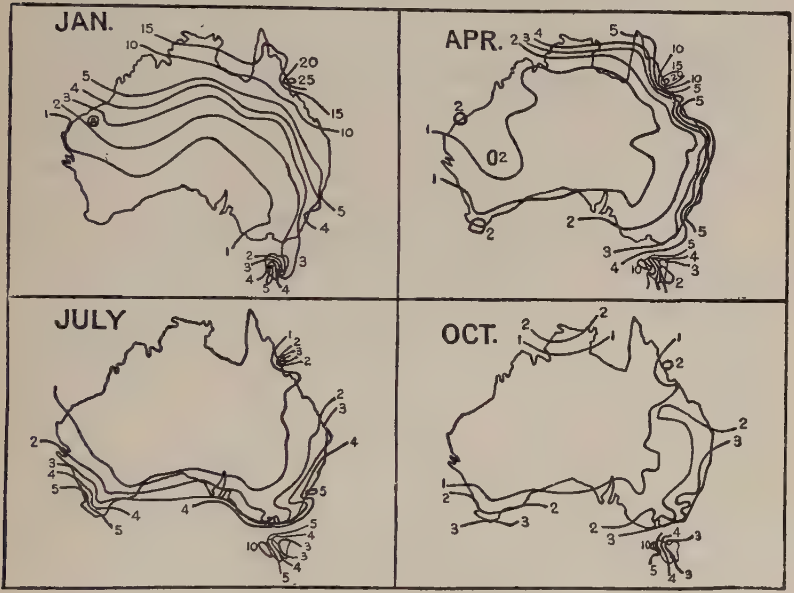


FIG. 148. Mean Rainfall.

Tasmania has a very heavy rainfall, more than 110 inches on the windward slopes of the mountains. Winter and spring are the rainiest seasons, but no month can be called dry. The rainfall is the greatest in the Commonwealth, except on the Queensland coast. But the east of Tasmania, in the lee of the mountains, has less than 20 inches, the contrast between the wet west and dry east being very sharp.

The uncertainty of the rainfall in Australia, the great danger of droughts, is most serious in those regions where the mean annual amount is between 10 and 30 inches, especially in New South Wales and Victoria; for settlers have established large farms which flourish in years of good or average rain, but fail in bad years, and general ruin results. Even in normal years much of the rain falls in short heavy thunderstorms, and, as evaporation is very rapid, a large proportion of the rain is wasted. It is estimated that only 1·5 per cent. of the rainwater of the basin of the River Darling above Bourke flows past that town. Most of the rivers dry up, or become merely a string of water holes, long before they can reach the sea or Lake Eyre. Lake Eyre itself is usually a great plain of salt; only occasionally does it contain water. A station on the Darling once recorded no appreciable rainfall for thirty months. Sometimes the drought year is an isolated occurrence, preceded and followed by years of plenty. At other times there is a series of years of deficient rainfall, ending with an especially dry year, and the consequences are exceedingly disastrous. It has been noticed that droughts are almost always accompanied by abnormally high barometric pressure; in other words, rain is scanty when the anticyclones are extensive and separated merely by slight cols, not by deep troughs, so that there is a continuous high-pressure ridge fending off the Antarctic cyclones, and also preventing the monsoonal rains of the north of the continent from extending south. The summer rain fails more often than the winter. The rainfall statistics for Monkira, south-west Queensland, are suggestive; the mean annual rainfall is 9 inches, but in one year there fell 29 inches, in another only 2 inches; 11 inches once fell in a single day. The variation at the state capitals is as follows:

Annual Rainfall

	Mean. Inches.	*Highest on record.* Inches.	*Lowest on record.* Inches.
Perth	33	47	20
Adelaide . . .	21	31	13
Melbourne . . .	25	37	16
Sydney . . .	48	83	21
Brisbane . . .	47	88	16
Hobart	23	41	13

Evaporation is hardly less important in determining humidity than is the rainfall, with which it tends to vary inversely. In the arid interior the mean annual evaporation from a water surface exceeds 100 inches. It is much less in the rainier regions, 66 inches at Perth, 39 inches at Melbourne, 38 inches at Sydney.

CHAPTER XLVII

AUSTRALIA: TROPICAL CYCLONES; HOT WINDS AND COLD WINDS

Tropical Cyclones. Both the north-west and the north-east coasts are sometimes visited by destructive hurricanes of the same kind as, for example, those of the West Indies (Fig. 149). These revolving storms are called Willy-willies on the north-west coast. They originate over the hot Timor Sea, and travel first to the south-west off the coast, the sequence of wind and weather on land indicating their proximity. The pearl fishers at sea often suffer severe losses. But it is only after the storms recurve to the south-east that the coast usually suffers. They strike inland generally between Condon and Fortescue, and work all the havoc for which tropical cyclones are noted. Thence they continue in the same direction over the interior of West Australia towards the Great Australian Bight, but, as is usual with tropical cyclones, their violence is exhausted when they leave the sea, and they are rather welcomed in the interior for the rain they bring. If they continue as far as the Southern Ocean they assume the form there of extra-tropical depressions of the ordinary type. They occur during summer and autumn, usually one or more each year. Very heavy downpours of rain may fall on the north-west coast during their passage. Places with a mean annual rainfall of some 12 inches have received more than 20 inches from a single

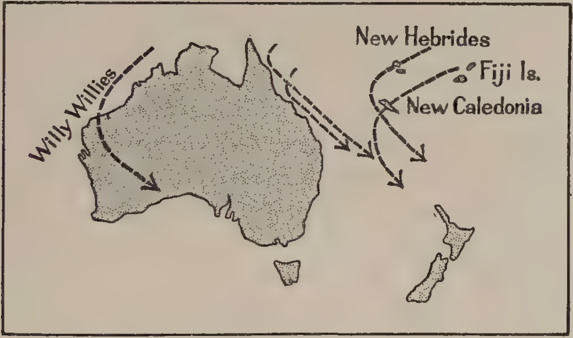


FIG. 149. Typical paths of tropical cyclones.

storm. Neither South Africa nor South America have tropical cyclones in the corresponding localities. Their occurrence in the north-west of Australia is no doubt due to the existence of very warm seas round the north and north-west of the continent, and the absence of a cold current off the west coast.

It is not surprising to find tropical cyclones to the north-east of Queensland (Fig. 149), since this region corresponds to the China Sea in the northern hemisphere. The cyclones spring up in the neighbourhood of the Fiji Islands, where they do great damage. Some reach the Queensland coast near Cairns, and then recurve towards the south-east on the usual parabolic course. But occasionally they continue westward to the Gulf of Carpentaria. They work great havoc on the Queensland coast, and sometimes there are phenomenal falls of rain. Fortunately most cyclones recurve before the coast feels their full violence. They very rarely reach the coast of New South Wales.

Hot winds and Cold winds. The south of Australia is sometimes visited by very hot, dry, and dusty winds blowing from the deserts of the interior. The temperature has been known to rise to 120° in the north of Victoria. Melbourne has recorded a maximum of over 100° on six consecutive days, when the pressure distribution was such as to cause a steady flow of air from the north. 'In Victoria the hot winds are known as "Brick Fielders", a name originally applied to the "Southerly Bursters" in Sydney because of the dust they raised from the brickfields to the south of the city. When the gold fields were discovered in Victoria the miners hailing from Sydney gave the name to the dusty winds from the opposite quarter.' (*Australia Year Book.*)

On the east coast of the continent hot winds are not so prominent a feature as cold winds from the south, known as Southerly Bursters, really a closely related phenomenon. We have seen that a pair of anticyclones moving eastward are often separated by a trough of low pressure, or by a secondary, projecting in the form of an inverted V from an Antarctic cyclone. When the trough extends, as is sometimes the case, almost from the south to the north of the continent, the temperature falls suddenly as the line of lowest pressure passes any point, since in front of it there is a warm wind from a northerly direction, and in rear a cold south wind. The longer the trough, the greater the distance the air currents travel, and, therefore, the greater the temperature excess of the north wind, and deficit of the south wind. The north winds are the hot winds of South Australia and Victoria, the heat being the greater owing to the proximity of the hot deserts; but on the coast of New South Wales, especially about Sydney, the cold winds in rear of the trough are more prominent. After a day or more of hot sultry weather with a northerly wind there is a short lull, and then very suddenly, when the line of lowest pressure has passed, a strong, often violent, wind sets in from the south. A striking roll of cumulus cloud may accompany the Burster, and there is usually heavy rain. Temperature drops suddenly, generally as much as 20°. The phenomenon is most frequent in spring and summer. Its intensification on the coast of New South Wales is attributed by the local meteorologists largely to the topography, one important suggestion being that the Eastern Highlands impede the advance of the second of the pair of anticyclones; the southerly winds do not start till the barometric gradient has become steep enough to overcome the resistance of the barrier, when they set in with gale force.

CHAPTER XLVIII

NEW ZEALAND

The main climatic features of the Dominion are readily understood from a consideration of its geographical position and relief. The islands lie within the influence of the variable westerlies of the south hemisphere all the year; the prevailing winds blow strongly from north-west, west, and south-west. The meteorological situation corresponds to that of the British Isles. In summer, when the climate belts have swung south, the south-east trades are sometimes felt on the northern peninsula of the North Island. The rest of the North Island is then just on the border of the westerlies, and enjoys much less windy and rainy weather than in winter.

The temperature is equable for the latitude. The annual range is least on the west coast, 16° at Hokitika; at Christchurch on the east coast it is 19°. The small range is, of course, due to the vast surrounding ocean. The winters are very mild, the summers very cool. New Zealand is in the same latitudes as Italy, part of it indeed is nearer the Equator, but the mean summer temperature is more than 10° lower, and the extremes of heat are very much less; at Auckland in the north 88° is not often exceeded. The winters are slightly warmer in New Zealand than in Italy. Dunedin has very similar temperatures to those of Falmouth, which is 400 miles nearer the Pole; Auckland is comparable with Lisbon. Frost does not occur in most winters near the coasts of North Island. The west coast is a little warmer than the east in winter owing partly to the warmer sea-water brought by the East Australian current, partly to the damper air and cloudier sky. In summer the east coast is the warmer, being to leeward of the heated interior. Thus the east coast has slightly more extreme temperatures.

The Dominion has more sunshine than might be expected in a moist oceanic climate. In the east of the islands there is almost as much as in Italy, considerably more than in the British Isles. Napier has the highest record with an annual average of 2,550 hours, and most of New Zealand has over 2,000 hours. Rome has 2,400 hours, the south of England only about 1,700 hours.

The rainfall is strongly reminiscent of that of the British Isles both in amount and distribution. The relief is similar in the two regions, the land rising rapidly from the west coast, and forming a high mountain barrier on the windward side. But in the South Island of New Zealand the mountains are higher and more continuous, rising to over 10,000 feet, and the area with excessive rainfall is greater. There is a wide strip, including the west coast and the mountains, which receives more than 100 inches of rain a year, and much of the higher land has 200, and probably parts of it 300, inches. Much of the precipitation falls as snow on the mountains, and there are vast snowfields which are drained by large glaciers. The Franz Josef glacier, in a valley on the west of South Island in the latitude of Florence, descends within 700 feet of sea level. East of the mountains the rainfall decreases very rapidly. In most of the eastern half of South Island there is less than 40 inches, in part of eastern Otago less than 20 inches, the lowest mean annual total registered in the Dominion being 14 inches at Clyde, which is situated in the interior of South Island just east of the mountains. The Canterbury Plains have from 20 to 30 inches.

There is an important connexion between the rainfall and temperature under certain weather conditions in South Island. As everywhere in the zone of the westerlies, the weather is controlled by a procession of cyclones. They move usually from south-west to north-east in the neighbourhood of New Zealand, and pass either south of the islands or over the extreme south of South Island. The approach of a cyclone will, therefore, be indicated in most of the Dominion by north winds, veering to north-west. The excessive rainfall of the west coasts and mountains is due to the ascent of these vapour-laden winds. The condensation liberates latent heat, and as the winds descend the eastern slopes they are dry and abnormally warm—in fact, föhn winds. No doubt the effect is often intensified in New Zealand by the westerly winds being derived from the hot interior of Australia. They are then very warm owing to their origin, and hence are able to pick up the more water vapour as they cross the sea, so that much latent heat is liberated on condensation. These north-west winds are very hot and enervating on the Canterbury Plains. As the cyclone passes on towards the north-east, the wind veers to south-west, and being derived from a polar quarter it is very cool and damp, but refreshing after the previous heat.

No part of North Island has so much rain as the west of South Island, no part so little as the east, since the mountains are not nearly so continuous. Most of the higher mountains receive more than 75 inches a year, Egmont more than 100 inches. Ruapehu is the only peak in North Island which has any glaciers, and they are very small.

The rain is evenly distributed over the year. The cyclonic activity of the westerlies appears to be almost as great in summer as in winter. The periodicity of the rainfall is greatest in North Island, which in summer is, to a certain extent, free from the influence of the stormy westerlies. Winter is the rainiest season, July the rainiest month; March is the least rainy month, with about half as much rain as July. But in oceanic New Zealand there is no real dry season; the rainfall periodicity is not nearly so pronounced as in the Mediterranean region of Europe, with which the north of New Zealand has some affinity in climate. In South Island the rainfall is remarkably evenly distributed over the year. At Hokitika on the west coast the mean is almost the same in every month. In the east the difference in the monthly totals is greater, but it is quite unimportant. The even rainfall, combined with the equable temperature, produces an evergreen vegetation.

MEAN TEMPERATURE (°F.)

AUSTRALIA

Queensland.

Station.	Alt. Feet.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.	Range.
C. York	69	80·4	80·6	80·2	80·1	80·1	77·5	76·6	*76·1*	77·0	79·7	81·1	**81·7**	79·3	5·6
Brisbane	137	**77·1**	76·4	74·3	70·2	64·4	59·9	*58·0*	60·6	65·2	69·8	73·3	76·5	68·8	19·1
Cloncurry	696	86·9	84·8	83·0	77·6	70·9	64·1	*61·3*	66·9	72·4	82·5	85·2	**88·0**	76·9	26·7
Charleville	975	**82·8**	80·2	75·8	68·8	60·2	53·5	*51·0*	56·5	62·8	71·6	77·4	80·2	68·4	31·8

New South Wales.

Station.	Alt. Feet.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.	Range.
Port Macquarie	49	**73·0**	73·0	70·5	65·8	60·6	55·8	*54·5*	56·8	60·3	63·9	67·8	71·2	64·4	18·5
Sydney	146	**71·6**	71·0	69·2	64·5	58·6	54·3	*52·3*	54·8	58·8	63·4	67·0	70·0	63·0	19·3
Bourke	460	**84·2**	82·6	77·5	68·5	58·5	54·1	*51·4*	55·9	62·8	70·0	75·7	82·2	68·5	32·8
Broken Hill	1,000	**78·6**	78·2	72·0	64·0	56·6	51·1	*49·2*	52·6	58·4	65·9	72·9	76·6	64·7	29·4
Wilcannia	267	**81·4**	79·9	74·0	65·4	57·7	52·3	*50·0*	53·9	60·2	68·2	74·8	79·4	66·4	31·4
Dubbo	870	**78·7**	77·3	70·9	64·1	55·2	49·4	*47·4*	50·5	56·1	63·4	70·7	76·3	63·3	31·3
Kiandra	4,640	56·3	**56·8**	51·6	45·5	38·1	35·2	*31·6*	34·3	39·7	44·1	51·8	55·6	45·0	25·2

Victoria and Tasmania.

Station.	Alt. Feet.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.	Range.
Sale	30	65·8	**66·5**	63·1	58·4	53·2	49·1	*47·5*	49·9	52·4	56·0	61·4	64·0	57·3	19·0
Melbourne	115	**67·5**	67·2	64·7	59·6	54·1	50·3	*48·5*	51·0	53·9	57·5	61·3	64·5	58·3	19·0
Hobart	160	62·0	**62·2**	59·4	55·4	560·	47·1	*45·7*	48·1	50·8	54·0	57·3	59·8	54·3	16·5

MEAN TEMPERATURE (°F.), *continued*

AUSTRALIA (*continued*)

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*	*Range.*
Western Australia															
Wyndham	23	88·0	88·0	88·2	86·7	81·9	77·5	*75·7*	79·2	84·9	89·2	**90·1**	90·0	84·9	14·4
Broome	63	**85·9**	85·4	85·4	83·1	76·4	71·2	*70·3*	72·4	77·0	81·0	84·6	85·9	79·8	15·6
Onslow	13	85·3	**85·3**	84·0	79·7	70·9	64·9	*63·7*	65·7	69·3	74·1	79·0	83·1	75·4	21·6
Carnarvon	15	79·8	**80·6**	79·4	74·7	67·9	62·7	*60·6*	62·6	65·6	69·0	73·0	76·9	71·1	20·0
Geraldton	13	74·1	**75·0**	73·4	68·7	63·7	60·1	*58·6*	59·4	61·0	63·7	68·4	72·1	66·5	16·4
Perth	197	73·5	**74·1**	71·1	66·4	60·4	56·2	*55·0*	55·9	58·0	60·9	65·4	70·6	64·0	19·1
Eucla	30	70·8	**71·1**	69·3	66·1	60·8	55·9	*54·3*	56·2	59·2	62·7	65·9	69·2	63·5	16·8
Nullagine	1,265	**89·8**	88·6	84·2	77·3	68·5	61·1	*59·3*	63·9	71·0	78·2	85·8	88·8	76·4	30·5
Coolgardie	1,389	**77·3**	75·5	71·3	65·4	57·5	52·3	*50·8*	53·3	58·2	63·5	71·0	76·0	64·4	26·5
Northern Territory.															
Darwin	97	84·0	*83·4*	84·1	**84·2**	81·9	78·9	*77·2*	79·5	82·7	85·5	**85·7**	85·3	82·7	8·5
Daly Waters	700	86·8	85·5	83·8	80·4	74·7	70·4	*68·6*	72·8	79·8	86·1	**88·3**	88·1	80·4	19·7
Alice Springs	2,000	**84·0**	82·3	76·7	68·1	59·7	54·4	*52·4*	58·3	65·6	73·5	79·5	82·4	69·7	31·6
South Australia.															
Adelaide	140	**74·2**	74·0	69·9	64·0	57·7	53·4	*51·5*	53·8	57·0	61·9	67·0	71·1	62·9	22·7
William Creek	250	**82·7**	82·5	76·1	67·2	59·2	53·9	*52·2*	56·2	62·4	70·3	77·1	81·4	68·4	30·5
NEW ZEALAND															
Auckland	260	66·6	**67·3**	65·7	61·3	57·0	53·8	*52·0*	52·0	54·5	57·0	60·4	64·2	59·4	15·3
Napier	7	**66·1**	65·5	62·9	58·6	53·8	50·1	*49·0*	49·9	53·6	57·5	60·7	64·2	57·6	17·1
New Plymouth	43	64·0	**64·6**	63·3	60·1	55·4	52·3	*50·2*	50·7	53·2	55·2	58·3	61·9	57·4	14·4
Wellington	142	**62·4**	62·2	61·0	57·4	52·9	49·6	*47·5*	48·6	51·1	54·0	56·8	60·8	55·2	14·9
Christchurch	20	**61·7**	60·8	58·5	53·1	48·4	45·0	*42·4*	43·9	48·6	52·7	56·3	60·8	52·5	19·3
Dunedin	500	**57·7**	57·4	55·4	51·4	47·3	44·1	*42·4*	44·1	46·8	50·7	53·2	56·3	50·5	15·3

MEAN RAINFALL (inches)

AUSTRALIA

Queensland.

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
C. York	69	**22·9**	18·6	16·9	8·1	3·7	0·5	0·6	0·4	*0·1*	0·1	2·0	8·2	82·0
Harvey Creek	coast	**30·9**	*22·2*	**32·2**	22·2	13·2	8·0	4·2	5·4	*3·7*	3·8	8·1	11·7	165·6
Brisbane	137	**6·4**	6·3	5·8	**3·6**	2·8	**2·6**	2·3	*2·1*	2·1	2·6	**3·6**	4·9	45·2
Cloncurry	696	**5·1**	4·9	2·7	0·9	0·4	0·3	0·5	*0·1*	0·5	0·5	1·1	3·0	20·0
Charleville	975	2·6	**3·3**	3·3	1·5	1·5	1·2	0·8	*0·6*	0·8	1·3	1·4	2·3	20·6

New South Wales.

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Port Macquarie	coast	5·9	**7·5**	6·5	5·9	5·6	4·6	4 5	3·8	3·9	*3·2*	4·1	5·9	61·5
Sydney	146	3·6	4·4	4·9	**5·4**	**5·1**	4·8	5·0	3·0	2·9	2·9	*2·8*	2·8	47·7
Bourke	456	**2·0**	1·9	1·6	1·4	1·1	1·0	*0·9*	0·9	1·0	1·1	1·3	1·1	15·2
Broken Hill	1,000	0·7	0·7	0·7	0·8	0·9	**1·2**	0·6	1·0	0·7	0·8	0·6	*0·6*	9·3
Wilcannia	267	1·0	0·8	1·1	0·7	1·0	**1·1**	*0·6*	0·8	0·7	0·9	0·7	0·8	10·2
Dubbo	870	**2·0**	1·9	1·8	1·9	1·9	2·0	1·5	1·9	1·9	*1·6*	1·8	2·0	22·3
Kiandra	4,640	4·1	*3·2*	4·0	4·4	5·3	**8·7**	6·6	5·9	6·9	6·6	4·9	3·9	64·5

Victoria and Tasmania.

Station.	*Alt. Feet.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year.*
Sale	30	2·1	*1·5*	2·0	1·9	1·8	**2·3**	*1·9*	2·0	**2·3**	2·2	2·1	2·1	24·2
Melbourne	115	1·9	*1·8*	2·2	**2·3**	2·2	2·1	1·9	*1·8*	2·4	**2·7**	2·2	2·3	25·6
Hobart	160	1·8	*1·5*	1·6	1·8	1·9	**2·2**	2·1	*1·8*	2·1	2·2	2·5	1·9	23·6

MEAN RAINFALL (inches), *continued*

Station.	Alt. Feet.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Western Australia.														
Wyndham	23	**9·7**	5·9	4·3	1·0	0·4	0·1	0	*0*	0·1	0·5	2·2	4·2	28·4
Broome	63	5·0	**6·4**	3·8	1·4	0·4	1·2	0·3	*0*	0·1	0	0·9	3·5	23·0
Onslow	13	0·5	0·7	0·8	0·3	1·6	**1·8**	0·9	0·5	0	*0*	0	0·2	7·2
Carnarvon	15	0·3	0·7	0·5	0·5	1·3	**2·8**	1·9	0·6	0·3	0·1	*0*	0·1	9·1
Geraldton	13	0·2	0·2	0·4	1·1	2·6	**4·6**	3·6	2·9	1·1	0·7	0·3	*0·1*	17·8
Perth	197	*0·3*	0·3	0·7	1·7	4·9	**6·6**	6·4	5·6	3·3	2·1	0·8	0·6	33·3
Albany	39	*0·6*	0·9	1·3	2·6	4·6	**5·3**	4·8	5·0	3·7	2·8	1·3	1·0	33·7
Eucla	30	0·7	0·5	0·9	1·2	**1·2**	1·1	0·9	1·0	0·8	0·7	0·7	*0·4*	10·1
Nullagine	1,265	**2·7**	2·0	2·6	1·0	0·5	1·1	0·7	0·5	0	*0*	0·4	1·2	12·7
Coolgardie	1,389	*0·4*	0·7	0·6	0·6	**1·3**	1·2	0·9	0·9	0·6	0·7	0·5	0·6	9·2
Northern Territory.														
Darwin	97	**15·3**	13·0	9·7	4·5	0·7	0·2	*0·1*	0·1	0·5	2·1	5·2	10·3	61·7
Daly Waters	700	6·1	**6·7**	5·0	1·0	0·2	0·3	*0·1*	0·1	0·3	0·8	2·2	4·1	26·9
Alice Springs	2,000	**1·8**	1·7	1·3	0·9	0·6	0·6	0·4	*0·4*	0·4	0·7	0·9	1·3	11·1
South Australia.														
Adelaide	140	0·8	*0·6*	1·1	1·8	2·8	**3·0**	2·6	2·4	1·8	1·8	1·0	0·8	20·6
William Creek	250	0·5	0·4	**0·8**	0·4	0·4	0·7	0·3	*0·3*	0·4	0·3	0·4	0·3	5·4
NEW ZEALAND														
Auckland	260	*2·6*	3·0	3·1	3·3	4·4	4·8	**5·0**	4·2	3·6	3·6	3·3	2·9	43·8
Wellington	142	3·3	*3·2*	3·3	3·8	4·7	4·9	**5·6**	4·4	4·0	4·1	3·5	3·2	48·1
Hokitika	13	9·9	*7·2*	9·7	9·3	9·8	9·7	9·1	9·4	9·1	**11·9**	10·7	10·6	116·5
Dunedin	500	3·4	2·7	3·0	2·7	3·2	3·1	3·0	3·1	*2·7*	3·0	3·3	**3·5**	36·8

PART VIII

ANTARCTICA

Though many of the major topographical features, and almost all the minor features are still uncertain, we know enough of the Continent to appreciate the main facts about the climate and their causes. Antarctica is an unbroken expanse of snow and ice—the few exposures of bare rock around the coasts are negligible from our point of view—, and almost certainly there is a continuous land surface below, though we should not forget the possibility that the ice sheet conceals channels of the sea dividing the land mass. The area may be estimated at 5 million square miles ; Antarctica is much larger than Australia with its 3 million square miles. The coastline is very regular, and there are only two large indentations, the Ross Sea south of New Zealand, and the Weddell Sea south of the Atlantic Ocean. It is known that a very large part, probably more than half, of the continent is a high plateau. Explorers who have had their base in the Ross Sea region have made us familiar with the plateau edge which forms the lofty wall, probably a line

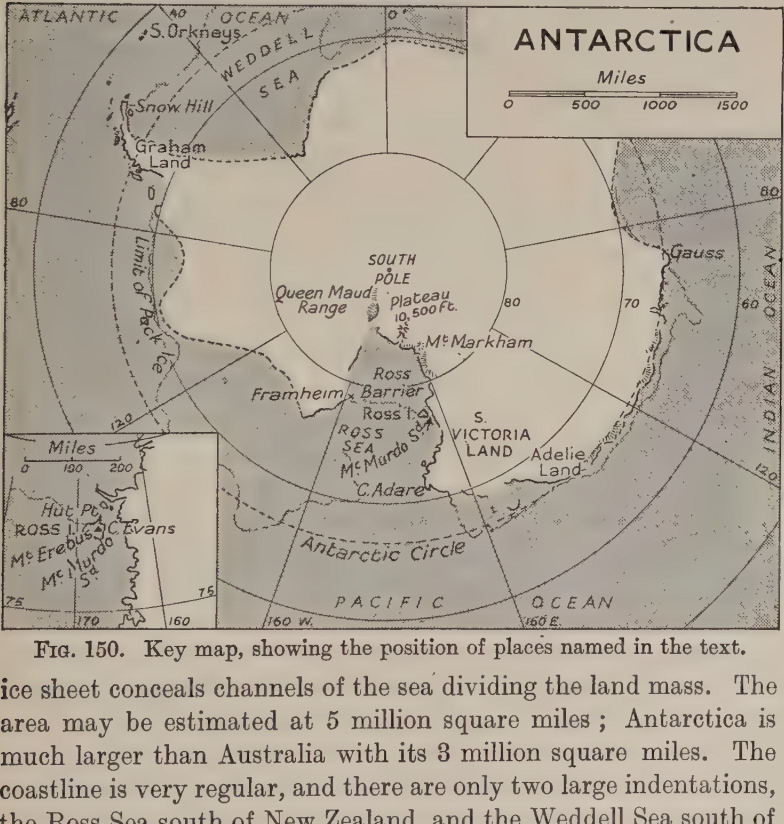

ANTARCTICA
Miles
0
500
1000
1500
ATLANTIC
OCEAN
40
0
S. Orkneys
WEDDELL SEA
Snow Hill
Graham Land
80
Limit of Pack Ice
SOUTH POLE
Queen Maud Range
Plateau 10,500 Ft.
80
70
Gauss
60
INDIAN OCEAN
80
Mt. Markham
Ross Barrier
Framheim
Ross I.
ROSS SEA
McMurdo Sd.
S. VICTORIA LAND
Adelie Land
C. Adare
Antarctic Circle
120
120
PACIFIC OCEAN
160 W.
160 E.
Miles
0
100
200
Hut Pt.
ROSS I.
C. Evans
Mt. Erebus
McMurdo Sd.
75
75
170
160

Fig. 150. Key map, showing the position of places named in the text.

of fracture, some 7,000 feet high along the west side of the Ross Sea and the Ice Barrier, then turns south-east (Maud Ranges) so as to include the South Pole, and continues towards the Weddell Sea. Probably most of the great tract on the Indian Ocean side of this line consists of an unbroken high plateau. The altitude of the South Pole itself is 10,000 feet ; the highest part crossed by Amundsen on his journey from Framheim on the east of the Barrier to the Pole was 11,000 feet. The edge of the plateau overlooks the Ross Sea from an altitude of between 7,000 and 8,000 feet, and behind the edge isolated peaks rise to considerable elevations above the general level, Mount Markham exceeding 15,000 feet above the sea. From the Indian Ocean the land rises steeply some thousands of feet to a plateau, and presumably the plateau block is continuous at an unknown altitude which may be estimated at 3,000 to 10,000 feet as far as the faulted edge just mentioned.

We have hardly any knowledge of the interior of that half of Antarctica which faces the Pacific. There can be little doubt that the surface is snow or ice, and there are reasons for supposing that it is of considerably less altitude than the rest of the continent, but Graham Land has a peak of 8,000 feet. The mean altitude of the whole of Antarctica has been estimated at 6,600 feet. It is the largest area of high plateau on the globe, a fact which is of the more importance meteorologically since the plateau includes and lies symmetrically about the Pole. The lengths of the summer days and winter nights, each six months at the Pole, are in themselves outstanding facts and fundamental controls of the climate.

A glance at a map shows the vast expanse of unbroken ocean surrounding Antarctica ; the oceans of the northern hemisphere are small by comparison. The climate over the southern ocean is remarkably uniform ; there are none of those sharp contrasts between very warm and very cold currents which bring about such strong climatic variations in similar latitudes in the northern oceans. The temperature is low, and pack-ice often extends hundreds of miles from the Antarctic coasts, the extent varying greatly from year to year ; the northern limit was 60° S. and 72° S. in consecutive years in the Weddell Sea area. The ocean helps to prevent very intense winter cold on the coasts, but it is also an important factor in the very cold summers. The Weddell Sea and Ross Sea indentations carry the oceanic conditions far south. The Ross Sea penetrates as far as about 78° S. lat., where it meets the ice cliffs of the Barrier, a snow-covered plain, probably floating ice, which continues the Ross Sea southwards to lat. 85° ; its altitude is about 170 feet. The dry powdery snow forms a very effective insulator from the heat of the sea. The Ross Sea itself is open water in summer, and much of the middle of it is open even during most of the winter.

There is perhaps sometimes a tendency to attribute more uniformity than really exists to the climate of Antarctica. Though the general features are very similar everywhere there must be considerable local differences such as were proved to exist along the south of the Ross Sea by the simultaneous records of Amundsen's and Scott's parties in 1911. The topography of that region favours large differences of climate, but considerable local peculiarities are also to be expected elsewhere.

The exhaustive examinations and discussions of the data available compensate to some extent for their scantiness. Special mention must be made of the work by Dr. G. C. Simpson on the results of the British Antarctic Expedition 1910–13.

Pressure and Winds.

It has long been known that the atmospheric pressure decreases towards the south from the sub-tropical high pressure belt of the southern hemisphere. Owing to the almost unbroken ocean which surrounds the earth in these latitudes, and the uniformity of the temperature distribution, the mean isobars are remarkably parallel in the belt of the Roaring Forties and higher latitudes, and it was formerly believed that the pressure went on decreasing as far as the Pole, the low pressure being caused by the strong centrifugal force in the polar whirl of westerly winds. It has, however, now been proved highly probable if not certain that Antarctica is covered by an anticyclone.

The low pressures of the Roaring Forties continue to decrease as far as the neighbourhood of the Antarctic circle, that is, almost to the shores of Antarctica. But there a change takes place, and pressure begins to increase towards the Pole ; the dynamical effect of the circumpolar whirl is more than counterbalanced by the thermal effect of the intense cold of the snow-covered continent which tends to produce high atmospheric pressure. The belt of lowest pressure is between 60° S. lat. and the Antarctic circle, but its position is variable, and appears to be determined by the extent of the pack-ice round Antarctica, the high pressures of the continent being continued to the limit of the pack-ice, which may change very much from year to year.

The low-pressure belt has prevailing westerly winds controlled by a procession of cyclones, the mean path of which is the trough of mean lowest pressure. In general character these cyclones are similar to those of the westerlies of the northern hemisphere, but they are deeper, and the winds stronger. It is a wild tract of open ocean, where gale follows gale with little interruption.

A proof that the zone of lowest pressure has been passed when ships make their way to the far south is the change in the prevailing winds from westerly to easterly, and this change has been reported by every expedition. The records have been remarkably consistent. The South Orkney Islands (lat. 61° S.) are just on the north side of the lowest pressures, and during her stay there in 1902–4 the *Scotia* found 71 per cent. of the winds westerly, only 2 per cent. easterly; but at Snow Hill, Graham Land (lat. 64° S.) south and south-south-east winds prevailed in the winter and spring of 1903. The *Gauss* expedition (lat. 66° S., long. 89½° E.) experienced easterly winds almost without interruption in 1902–3. There are longer records from the Ross Sea region. On Ross Island the *Discovery* expedition at Hut Point had prevailing ENE. winds in 1903, the British Antarctic Expedition at Cape Evans almost constant E., ESE., or SE. winds in 1911–13, these directions making 84 per cent. of the observations. At Framheim, on the east of the Great Barrier, Amundsen found E. winds in 1911, and SE. was the prevailing direction at Cape Adare also in 1911. During Mawson's journey on the plateau of Adelie Land in 1913 the terrific gales which blew almost continuously were from a southerly point. On the polar plateau itself Shackleton found SSE. to SSW. winds in the summer of 1908–9, Scott almost constant (73 per cent.) S., SSE. and SSW. winds on his last journey to the Pole itself in 1911, and Amundsen prevailing winds from the same directions (54 per cent.) on his march to the Pole in the same summer.

These records show that not only is the mean distribution of pressure over Antarctica anticyclonic, but also the anticyclone is very constant in position. Direct observations of pressure, which show the increase towards the Pole, are also available, but as they are not synchronous, the conclusions to be drawn are probable rather than certain. The mean annual pressure in the zone of lowest pressure is probably under 29·1 inches; at Cape Adare it was 29·19, at Cape Evans 29·26. In the heart of the continent the very few records that have been made are quite insufficient for comparison with mean values, and further uncertainties are introduced by the fact that the exact altitude of the plateau is unknown, and even if the altitude was known, the reduction of the barometer readings for comparison with the sea-level pressures would be very difficult. All the records agree in showing considerably higher pressures in summer than in winter.

The prevailing southerly to easterly winds are the natural circulation round the anticyclone, but there is another factor. On such snow-covered domes as Antarctica and Greenland the air resting on the surface is so much chilled that its increased density makes it flow down the slopes more or less radially from the highest parts; from whatever side the South Pole is approached head winds are encountered. In some places the descending winds are very strong owing to the steep gradient and the slight friction on the smooth snow. Possibly the blizzards of certain regions are produced in this way, and probably the extraordinarily violent winds which Mawson found to rage almost continually in Adelie Land with a mean speed of 50 miles an hour, have in part the same cause, acting in a specially favourable topography.

Many features of the weather which seem to be common to most of Antarctica are easily understood if the conditions are anticyclonic—the clear sky and hence very vigorous radiation of heat from the snow surface, the dry air, the scanty precipitation, the frequency of calms and light winds.

The anticyclone, being due to the intense cold of the snow surface, is essentially a shallow system not more than some few thousand feet deep, and above it the general polar cyclone must exist in an intensified form. The upper winds are best shown by the movements of the clouds and by the drift of the smoke from the volcanic Mount Erebus (13,000 feet). In the McMurdo Sound region the clouds between 10,000 and 13,000 feet and the smoke from Erebus indicated prevailing winds between west and north, the opposite of the surface direction on the Barrier, and associated presumably with the cyclonic circulation of the middle atmosphere (Fig. 151).

But though the weather is anticyclonic in its main features, cyclonic characteristics are not lacking. Boisterous weather, violent winds with driving snow, ‘ blizzards’, have been reported by all explorers. The essential element in the blizzard is the strong wind, generally from the south, but in most cases an equally important feature is the thick whirling snow that fills the air so that it is impossible to see more than a few yards, and the traveller is bewildered and lost ; how much of the snow is swept up from the ground, how much descends from the clouds it is impossible to say, but probably most of it is new snow from above. The blizzard usually springs up very quickly, a calm changing within a few hours to a wind blowing in furious gusts of 30 to 50 miles an hour (Fig. 152) ; the storm may last for a few hours or even a few days.

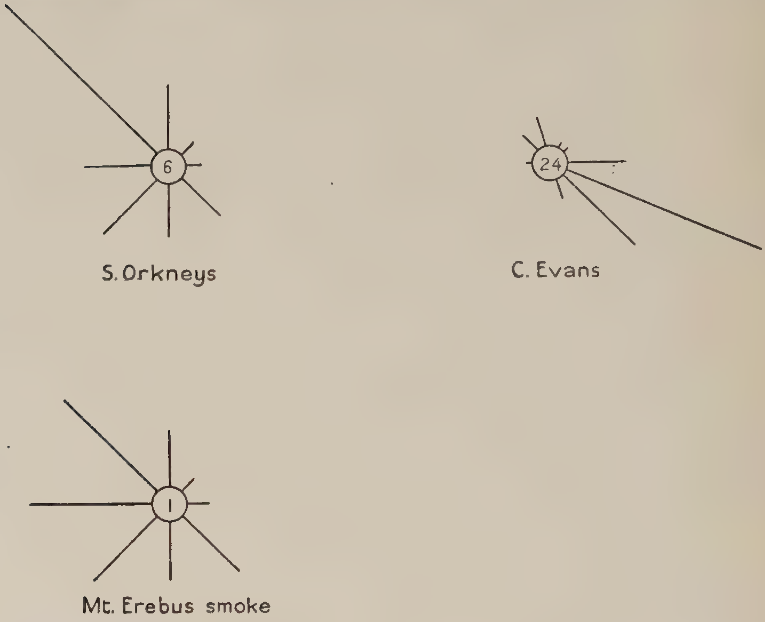


Fig. 151. Mean wind directions. The lines, read towards the centre, are proportional to the frequencies. The figures at the centres denote percentage of calms and variable winds.

In winter the temperature rises suddenly when the storm begins, a rise of as much as 32° having been recorded, but in summer it generally becomes colder.

In 1911–12 blizzards were raging during almost a quarter of the time at Cape Evans, but they were almost unknown at Framheim. Cape Adare had a remarkably high proportion of calms, the wind being under 5 miles per hour for over 70 per cent. of the period of observation, and yet hurricanes (not, however, the blizzard type) of over 70 miles per hour occurred each month. Evidently the wind is controlled largely by the topography round the station. On the coasts such storms might well seem, on first consideration, to be associated with the passing cyclones of the variable westerlies, the southern sectors of which may sweep the edge of Antarctica. But it is difficult to apply this explanation to the blizzards which formed so prominent a feature of the weather on the west of the Barrier, far from the open ocean. The examination of his own records at Cape Evans and those made simultaneously at Framheim and Cape Adare, has convinced Simpson that the disturbances in the Ross Sea region, at any rate, are quite unconnected with the cyclones of the westerlies, and are not even circular cyclonic systems, but pressure waves or surges which move outwards from the Pole. The steep and lofty plateau edge which bounds the barrier on the west is thought by him to be the cause

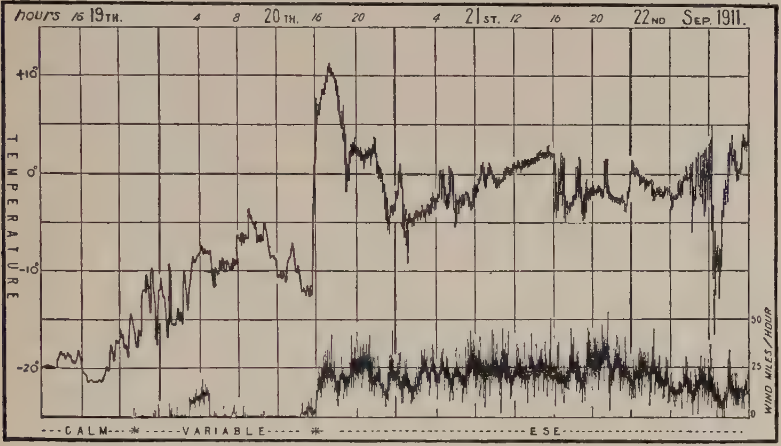


FIG. 152. Wind velocity and temperature, C. Evans. The blizzard started at 16 h. on the 20th. (British Antarctic Expedition results: Simpson.)

of the great frequency of blizzards there, owing to the obstacle it presents to the east winds. At any rate it would seem that the very frequent blizzards on the west of the Barrier, which were an important factor in the disaster to Scott's Polar party, are a local feature, for Amundsen, whose route led across the Barrier much farther to the east, found comparatively light winds (Simpson, *Scott's Polar Journey and the Weather*).

At Framheim in 1911 42 per cent. of the observations were calms or very light winds of under 4 miles an hour, and only 2 per cent. winds over 30 miles per hour, but at Cape Evans (1911–12) only 22 per cent. were calms or light winds and 30 per cent. winds more than 30 miles per hour. The high percentage of calms shows dominant anticyclonic conditions at both stations ; the frequency of high winds at Cape Evans is an expression of the curious frequency also of the opposite conditions, raging blizzards.

More than one theory of blizzards has been advanced. Simpson's, based on his experiences in the Ross Sea region, depends on the existence on the surface of a calm layer of very cold dense air already referred to, a layer so dense that even strong winds in the higher atmosphere can slide over it, while the calm persists below. But when the air movement aloft becomes still more vigorous eddy motion gradually extends downwards and in a short time the whole of the surface layer is churned up and mixed with the gale above. Thus the blizzard is merely the extension to the surface of a very strong wind in the higher atmosphere, which is due to a temporary steepening of the barometric gradient. This theory goes far to explain the frequency both of calms and of high winds as compared with winds of moderate strength. It also explains the sudden rise in temperature that occurs at the beginning of a winter blizzard, the very cold surface air being removed and mixed with the warmer general air currents.

Temperature.

It was to be expected that the Antarctic winters would prove very cold. A more striking feature is the coldness of the summers. So cold are they that land animals (except birds) and flowering plants are almost completely absent and there are no human settlements. The astronomical facts suggest warmer conditions, for in the southern summer the earth makes its nearest approach to the sun, and on December 21 there is a greater amount of insolation received from the sun in the 24 hours above the South Pole than at any other latitude on any day of the year. But the air temperature depends much more on the temperature of the surface of the earth with which the air is in contact than on the direct passage of the rays of the sun. The long oblique course through the atmosphere weakens the insolation so much before it reaches the earth that even when the sun is at its greatest altitude it is never powerful enough to melt the snow, the temperature of which, and consequently the air temperature also, remains well below freezing-point. There is little doubt that the mean temperature of the warmest month everywhere inside the Antarctic circle is below 32° ; in this region the highest readings are not in the interior of the land mass, but on the coasts of the boisterous Southern Ocean, where the mean temperature in December and January is probably about 30° ; at Cape Evans the mean temperature for these months is about 24°. The mean January temperature on the Barrier is estimated at 15°. At McMurdo Sound (see Table) the mean daily maximum temperature is below 32° in every month, but probably the temperature rises above 32° once or twice in December and January in most years ; but it may also sink almost to zero.

MEAN MONTHLY TEMPERATURES (° F.)

	McMurdo Sound, 5 years (C. Evans and Hut Pt. records combined).	*Framheim, 1911–12.*	*C. Adare (computed by Simpson).*	*'Gauss,' lat. 65° S., 1902.*	*Snow Hill, Graham Land, lat. 64½° S., 1902–3.*	*S. Orkneys, 1903–4.*
Jan.	23·7	14·5	(31·6)	30·6	30·0	31·4
Feb.	15·8	(4·2)	(27·0)	(25·9)	24·4	31·5
Mar.	4·4	(−6·7)	18·7	16·9	12·5	31·3
Apr.	−8·8	−17·7	9·4	3·9	6·5	22·8
May	−10·5	−31·7	−2·2	6·8	0·0	13·8
June	−11·9	−29·9	−14·5	0·5	−3·6	13·1
July	−14·6	−33·7	−11·9	−0·6	−6·0	11·8
Aug.	−14·6	−48·6	−13·6	−7·4	−2·9	15·7
Sept.	−11·7	−35·5	−7·5	0·1	2·8	16·9
Oct.	−2·1	−11·6	−0·6	8·6	14·0	22·7
Nov.	14·2	4·1	18·5	19·9	16·5	30·2
Dec.	24·9	19·9	29·5	30·0	28·1	30·1
Year	0·7	−14·4	7·0	11·3	9·4	22·6

For the Polar plateau we have the records made in December 1911 and January 1912 by Amundsen and Scott. The mean temperature observed in December was −8·6, in January −18·7. The lowest record was −19·3 in December and −29·7 in January; the highest maximum, 5·5 in December and −3·2 in January. From December 22 till February 6, the period during which he was on the Plateau, Scott did not once record a reading above zero. The great fall in temperature from December to January shows how rapidly the temperature responds to the changing attitude of the sun, a result of the good insulation of the dry snow.

TEMPERATURE (° F.) AT McMURDO SOUND (CAPE EVANS (2 YEARS) AND HUT POINT (2 YEARS) RECORDS COMBINED)

	Mean.		*Absolute.*	
	Daily Maximum.	*Daily Minimum.*	*Maximum.*	*Minimum.*
January . .	28·9	16·9	39·9	4·0
February .	20·0	8·7	33·1	−9·5
March . .	9·4	−2·2	27·5	−20·0
April . .	−2·0	−15·5	19·5	−42·0
May . .	−5·2	−20·7	17·0	−51·2
June . .	−4·9	−22·4	20·6	−47·0
July . .	−6·1	−23·6	15·9	−54·2
August . .	−6·5	−23·8	17·8	−53·2
September .	−5·1	−22·7	15·9	−58·5
October . .	2·2	−12·1	24·1	−42·8
November .	18·6	7·3	34·0	−6·5
December .	28·6	18·3	42·0	4·2

In summer the sun is above the horizon all the 24 hours for at least one day everywhere in Antarctica. At the Pole its altitude is almost constant throughout the 24 hours of each day during the 6 months that it is above the horizon, though it rises slightly higher day by day from the horizon to a maximum altitude of 23½° on December 21, and presumably the mean diurnal range of temperature is very small; during the 4 days January 16–20, when Scott was at or within 30 miles of the South Pole, the highest reading was −19·1, the lowest −26·7. But the difference between the midday and midnight altitudes of the sun becomes greater and greater with decreasing latitude; thus at lat. 70° the altitude is 43½° at midday, only 3½° at midnight, on December 21. The consequent diurnal range in temperature is remarkably great; on the Barrier members of Scott's party recorded a mean amplitude of 20° during a spell of 6 calm clear days in November, and the mean amplitude during November, December, and January was 11°. But at McMurdo Sound the figures were far lower, the highest figure, that for January, being only 5°. The high range on the Barrier is explained by the presence of the thick layer of dry loose snow on its surface. This forms an excellent heat insulator, and consequently the varying intensity of insolation as the sun rises and sinks in the sky is reflected strongly in the curve of air temperature. The range is considerably greater in the early part of the summer when the snow is very dry and loose than towards the end of the season. It is probably for the same reason that the warmest month is December and not January; the decreasing altitude of the sun after the solstice has an almost immediate effect on the air temperature, which falls very rapidly; from May to September there is little change in the intense cold from month to month.

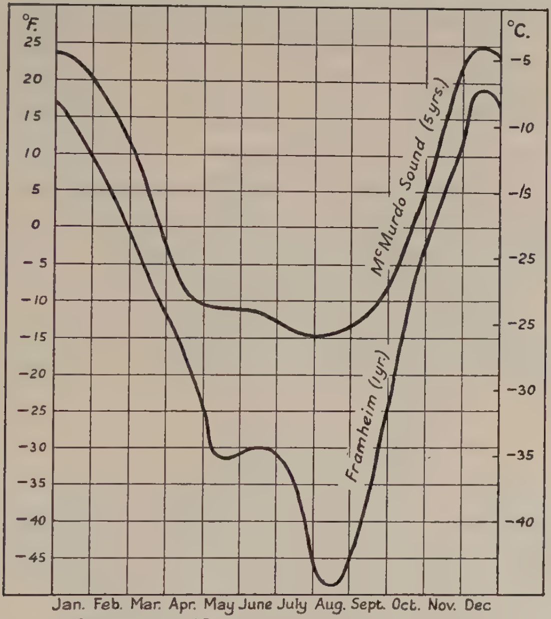


Fig. 153. Mean monthly temperature.

The winter temperatures on the Polar plateau have never been observed, but the mean for July is probably very low. On the Barrier it has been estimated at well below −35°. The lowest reading recorded was −76°, taken on the Barrier near Ross Island on July 6, 1911. Other low readings were −57° (Shackleton) and −67° on September 15, 1903, near the winter quarters of the *Discovery* on Ross Island. The mean temperature for August is −15° in McMurdo Sound, but it is very much lower at Framheim, −49° (Fig. 153); this difference is probably related to the absence of blizzards at Framheim, where the surface layer of supercooled air is not often churned up and dissipated, while at McMurdo Sound the frequent blizzards, though one of the greatest trials of life, bring higher temperatures. The winter temperatures are naturally much higher on the ocean coasts, but the means are probably everywhere below zero. The middle of the Ross Sea is much warmer than its coasts, for the winter pack ice is thin and sometimes not continuous.

The very cold Antarctic winters are not surprising on a great snow-covered plateau lying round the Pole itself, much of it without any insolation for several months to replace the extremely rapid loss of heat by radiation. Possibly the centre of Antarctica has the coldest winters of the whole world, but we have no records to prove it; the winters of the Ross Sea region and the ocean coasts are by no means so cold as those of the interior of eastern Siberia.

Precipitation.

There are few, if any, reliable statistics of the amount of precipitation, but it is known to be scanty, equivalent probably to not more than 10 inches of rain; it all falls as snow, mostly fine crystals, dry and powdery. The difficulty in measuring it is due to the strong winds which almost always accompany it, for the snow is whirled about and cannot settle in a gauge. Moreover, it is impossible to say how much of the snow is newly fallen from the clouds, how much has been swept up from the ground.

A perplexing problem is the cause of the precipitation in view of the anticyclonic conditions which prevail. That precipitation exceeds evaporation—and evaporation is certainly considerable—seems to be proved by the great glaciers that move down from the plateau and by the calving from the edge of the ice sheet of the numerous icebergs that beset the surrounding ocean. There must be considerable precipitation in the interior to feed this dispersal from the long periphery. The cyclones of the westerlies provide a considerable snowfall on the coasts that come within their influence, but their influence does not appear to extend far inland.

Antarctica enjoys very clear skies and long sunshine in the summer months, the sunshine traces being sometimes continuous for the whole 24 hours. In December 1903 the *Discovery* station at McMurdo Sound recorded 490 hours, 66 per cent. of the possible duration, and in a year there were 1,725 hours, which is more than we have in the sunniest parts of England, though the sun in Antarctica was above the horizon for only 246 days. The totals recorded by Scott's party at Cape Evans were :

November 1911	378 hours.
December 1911	433 ,,
January 1912	412 ,,
November 1912	335 ,,
December 1912	334 ,,

EQUIVALENTS

TEMPERATURE. °F. AND °C.

Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.
°	°	°	°	°	°	°	°	°	°
– 20·0	– 28·9	+ 10·0	– 12·2	+ 40·0	+ 4·4	+ 70·0	+ 21·1	+ 100·0	+ 37·8
19·5	28·6	10·5	11·9	40·5	4·7	70·5	21·4	100·5	38·1
19·0	28·3	11·0	11·7	41·0	5·0	71·0	21·7	101·0	38·3
18·5	28·1	11·5	11·4	41·5	5·3	71·5	21·9	101·5	38·6
18·0	27·8	12·0	11·1	42·0	5·6	72·0	22·2	102·0	38·9
17·5	27·5	12·5	10·8	42·5	5·8	72·5	22·5	102·5	39·2
17·0	27·2	13·0	10·6	43·0	6·1	73·0	22·8	103·0	39·4
16·5	26·9	13·5	10·3	43·5	6·4	73·5	23·1	103·5	39·7
16·0	26·7	14·0	10·0	44·0	6·7	74·0	23·3	104·0	40·0
15·5	26·4	14·5	9·7	44·5	6·9	74·5	23·6	104·5	40·3
15·0	26·1	15·0	9·4	45·0	7·2	75·0	23·9	105·0	40·6
14·5	25·8	15·5	9·2	45·5	7·5	75·5	24·2	105·5	40·8
14·0	25·6	16·0	8·9	46·0	7·8	76·0	24·4	106·0	41·1
13·5	25·3	16·5	8·6	46·5	8·1	76·5	24·7	106·5	41·4
13·0	25·0	17·0	8·3	47·0	8·3	77·0	25·0	107·0	41·7
12·5	24·7	17·5	8·1	47·5	8·6	77·5	25·3	107·5	41·9
12·0	24·4	18·0	7·8	48·0	8·9	78·0	25·6	108·0	42·2
11·5	24·2	18·5	7·5	48·5	9·2	78·5	25·8	108·5	42·5
11·0	23·9	19·0	7·2	49·0	9·4	79·0	26·1	109·0	42·8
10·5	23·6	19·5	6·9	49·5	9·7	79·5	26·4	109·5	43·1
10·0	23·3	20·0	6·7	50·0	10·0	80·0	26·7	110·0	43·3
9·5	23·1	20·5	6·4	50·5	10·3	80·5	26·9	110·5	43·6
9·0	22·8	21·0	6·1	51·0	10·6	81·0	27·2	111·0	43·9
8·5	22·5	21·5	5·8	51·5	10·8	81·5	27·5	111·5	44·2
8·0	22·2	22·0	5·6	52·0	11·1	82·0	27·8	112·0	44·4
7·5	21·9	22·5	5·3	52·5	11·4	82·5	28·1	112·5	44·7
7·0	21·7	23·0	5·0	53·0	11·7	83·0	28·3	113·0	45·0
6·5	21·4	23·5	4·7	53·5	11·9	83·5	28·6	113·5	45·3
6·0	21·1	24·0	4·4	54·0	12·2	84·0	28·9	114·0	45·6
5·5	20·8	24·5	4·2	54·5	12·5	84·5	29·2	114·5	45·8
5·0	20·6	25·0	3·9	55·0	12·8	85·0	29·4	115·0	46·1
4·5	20·3	25·5	3·6	55·5	13·1	85·5	29·7	115·5	46·4
4·0	20·0	26·0	3·3	56·0	13·3	86·0	30·0	116·0	46·7
3·5	19·7	26·5	3·1	56·5	13·6	86·5	30·3	116·5	46·9
3·0	19·4	27·0	2·8	57·0	13·9	87·0	30·6	117·0	47·2
2·5	19·2	27·5	2·5	57·5	14·2	87·5	30·8	117·5	47·5
2·0	18·9	28·0	2·2	58·0	14·4	88·0	31·1	118·0	47·8
1·5	18·6	28·5	1·9	58·5	14·7	88·5	31·4	118·5	48·1
1·0	18·3	29·0	1·7	59·0	15·0	89·0	31·7	119·0	48·3
– 0·5	18·1	29·5	1·4	59·5	15·3	89·5	31·9	119·5	48·6
0·0	17·8	30·0	1·1	60·0	15·6	90·0	32·2	120·0	48·9
+ 0·5	17·5	30·5	0·8	60·5	15·8	90·5	32·5	120·5	49·2
1·0	17·2	31·0	0·6	61·0	16·1	91·0	32·8	121·0	49·4
1·5	16·9	31·5	– 0·3	61·5	16·4	91·5	33·1	121·5	49·7
2·0	16·7	32·0	0·0	62·0	16·7	92·0	33·3	122·0	50·0
2·5	16·4	32·5	+ 0·3	62·5	16·9	92·5	33·6	122·5	50·3
3·0	16·1	33·0	0·6	63·0	17·2	93·0	33·9	123·0	50·6
3·5	15·8	33·5	0·8	63·5	17·5	93·5	34·2	123·5	50·8
4·0	15·6	34·0	1·1	64·0	17·8	94·0	34·4	124·0	51·1
4·5	15·3	34·5	1·4	64·5	18·1	94·5	34·7	124·5	51·4
5·0	15·0	35·0	1·7	65·0	18·3	95·0	35·0	125·0	51·7
5·5	14·7	35·5	1·9	65·5	18·6	95·5	35·3	125·5	51·9
6·0	14·4	36·0	2·2	66·0	18·9	96·0	35·6	126·0	52·2
6·5	14·2	36·5	2·5	66·5	19·2	96·5	35·8	126·5	52·5
7·0	13·9	37·0	2·8	67·0	19·4	97·0	36·1	127·0	52·8
7·5	13·6	37·5	3·1	67·5	19·7	97·5	36·4	127·5	53·1
8·0	13·3	38·0	3·3	68·0	20·0	98·0	36·7	128·0	53·3
8·5	13·1	38·5	3·6	68·5	20·3	98·5	36·9	128·5	53·6
9·0	12·8	39·0	3·9	69·0	20·6	99·0	37·2	129·0	53·9
9·5	12·5	39·5	4·2	69·5	20·8	99·5	37·5	129·5	54·2

INCHES AND MILLIMETRES

Inches.	Millimetres.	Inches.	Millimetres.	Inches.	Millimetres.	Inches.	Millimetres.	Inches.	Millimetres.
0·05	1·3	3·1	78·7	6·1	154·9	9·1	231·1	31·0	787·4
0·1	2·5	3·2	81·3	6·2	157·5	9·2	233·7	32·0	812·8
0·2	5·1	3·3	83·8	6·3	160·0	9·3	236·2	33·0	838·2
0·3	7·6	3·4	86·4	6·4	162·6	9·4	238·8	34·0	863·6
0·4	10·2	3·5	88·9	6·5	165·1	9·5	241·3	35·0	889·0
0·5	12·7	3·6	91·4	6·6	167·6	9·6	243·8	36·0	914·4
0·6	15·2	3·7	94·0	6·7	170·2	9·7	246·4	37·0	939·8
0·7	17·8	3·8	96·5	6·8	172·7	9·8	248·9	38·0	965·2
0·8	20·3	3·9	99·1	6·9	175·3	9·9	251·5	39·0	990·6
0·9	22·9	**4·0**	101·6	**7·0**	177·8	**10·0**	254·0	**40·0**	1016·0
1·0	25·4	4·1	104·1	7·1	180·3	11·0	279·4	41·0	1041·4
1·1	27·9	4·2	106·7	7·2	182·9	12·0	304·8	42·0	1066·8
1·2	30·5	4·3	109·2	7·3	185·4	13·0	330·2	43·0	1092·2
1·3	33·0	4·4	111·8	7·4	188·0	14·0	355·6	44·0	1117·6
1·4	35·6	4·5	114·3	7·5	190·5	15·0	381·0	45·0	1143·0
1·5	38·1	4·6	116·8	7·6	193·0	16·0	406·4	46·0	1168·4
1·6	40·6	4·7	119·4	7·7	195·6	17·0	431·8	47·0	1193·8
1·7	43·2	4·8	121·9	7·8	198·1	18·0	457·2	48·0	1219·2
1·8	45·7	4·9	124·5	7·9	200·7	19·0	482·6	49·0	1244·6
1·9	48·3	**5·0**	127·0	**8·0**	203·2	**20·0**	508·0	**50·0**	1270·0
2·0	50·8	5·1	129·5	8·1	205·7	21·0	533·4	51·0	1295·4
2·1	53·3	5·2	132·1	8·2	208·3	22·0	558·8	52·0	1320·8
2·2	55·9	5·3	134·6	8·3	210·8	23·0	584·2	53·0	1346·2
2·3	58·4	5·4	137·2	8·4	213·4	24·0	609·6	54·0	1371·6
2·4	61·0	5·5	139·7	8·5	215·9	25·0	635·0	55·0	1397·0
2·5	63·5	5·6	142·2	8·6	218·4	26·0	660·4	56·0	1422·4
2·6	66·0	5·7	144·8	8·7	221·0	27·0	685·8	57·0	1447·8
2·7	68·6	5·8	147·3	8·8	223·5	28·0	711·2	58·0	1473·2
2·8	71·1	5·9	149·9	8·9	226·1	29·0	736·6	59·0	1498·6
2·9	73·7	**6·0**	152·4	**9·0**	228·6	**30·0**	762·0	**60·0**	1524·0
3·0	76·2								

INDEX

Aar, R., 229.
Abercorn, 83.
Abo, 39.
Abyssinia, 19, 42–4, 82, 86.
Adalia, 152.
Adana, 152.
Adare, C., 377, 379, 381.
Addis Ababa, 43, 82, 86.
Addi Ugri, 86.
Adelaide, 350, 351, 352, 359, 360, 362, 370, 372.
Adelie Land, 376, 377.
Aden, 191, 195.
Aden, Gulf of, 44, 154.
Adriatic Sea, 197, 206, 222, 236, 237, 238, 239, 241, 245, 246.
Aegean Sea, 197, 206, 236, 238, 239, 245, 250, 251.
Afghanistan, 97, 98, 100, 114, 148–54, 242.
Agra, 113.
Agram, 222, 255, 259.
Agulhas, Cape, 13.
Ahaggar, 27.
Aian, 188, 277, 284.
Air, 27.
Akassa, 34, 81, 85.
Akita, 191, 195.
Akyab, 190, 193.
Åland Is., 171, 176, 181.
Alaska, 268, 273, 274, 277, 292.
Albacete, 243.
Albany, 299, 301, 372.
Albuquerque, 299, 301.
Alessandria, 256.
Alexandria, 22, 24, 40, 41, 81, 85.
Alexandrovsk, 181.
Algeria, 19, 22, 23, 238, 246.
Algiers, 23, 81, 85.
Alice Springs, 350, 351, 352, 359, 370, 372.
Allahabad, 113, 190, 194.
Alps, 200, 218, 221, 224–33, 239, 246, 249.
Altdorf, 227, 228, 232, 255, 259.
Alto da Serra, 330.
Amazon, 47, 307, 325–7.
Amboina, 191, 195.
America, Central, 335–9.
Amu-Daria, 172.
Amur R., 182, 186, 188.
Ancona, 236.
Andalusia, 248, 249.
Andermatt, 231, 255, 259.
Andes, 11, 47, 303, 308, 312, 314, 316, 318, 319–22, 323, 324, 327.
Angola, 60.
Angora, 151.
Angra Pequena, 75.
Annam, 95, 145.
Antananarivo, 84, 88.
Antarctica, 373–85.
Antioquia, 323.
Antofagasta, 315, 316.
Apennines, 246, 249, 250.
Appalachians, 262, 290, 298.
Arabia, 105, 109, 148–54.
Arabian Sea, 109, 121, 123.
Arakan, 112.
Aral, Sea of, 172.
Archangel, 182, 192, 196.
Arctic Ocean, 172, 177, 183, 197, 207.
Arequipa, 314, 342.
Argentine Rep., 303, 330–5.
Arica, 315, 316.
Arizona, 274, 277, 278, 288.
Armenia, 150.
Arosa, 230.
Asaba, 39.
Asia, Heart of, 154–62.
Asia Minor, 148–54, 238.
Assam, 102, 103, 105, 106, 111, 113, 117.
Assiut, 25, 40, 41, 82.
Astrakhan, 185, 192, 196.
Asuncion, 328, 340, 343.
Aswan, 25, 26, 42.
Asyut, 41.
Atacama, 316.
Athens, 5, 236, 242, 245, 246, 256, 261.
Athi plains, 51, 53.
Atlantic Ocean, 197, 201, 202, 203, 207.
Atlas, 19, 20, 22, 23.
Auckland, 366, 370, 372.
Aures, 23.
Austin, 278, 299, 301.
Australia: Pressure and winds, 353–6; Rainfall, 356–62; Temperature, 348–52; Tropical cyclones, hot winds and cold winds, 363–5.

Austria, 255, 259.
Azizia, 26.
Azores, 200, 202, 203, 242.
Azov, Sea of, 181.
Azul, 343.

Bagdad, 152, 153, 190, 191, 195.
Bahia, 314.
Bahia Blanca, 341, 343.
Bahr-el-Ghazal, 42.
Baikal, L., 172, 173, 175, 176, 177, 182.
'Bai-u', 142–3.
Bakersfield, 279, 280.
Baku, 192, 196.
Balboa, 344.
Balkan Peninsula, 149, 206, 218, 236, 238, 239, 243, 250–1, 255, 260.
Balkash, L., 184.
Baltic Sea, 177, 179, 181, 197, 219, 220, 222, 223, 242.
Baluchistan, 1, 17, 89, 114, 115, 148–54.
Banana, 46, 82, 86.
Bangalore, 112, 190, 193.
Bangkok, 145.
Barcelona, 256, 260.
Barnaul, 186, 193, 196.
'Barometric backbone' of Europe, 204.
Barren Lands, 262.
Basel, 208, 229, 231, 232, 255, 259.
Basra, 190.
Batavia, 144, 145, 191, 195.
Bathurst (Afr.), 30, 34.
Batum, 176, 192, 196.
Bauchi, 38, 85.
Bayonne, 257.
Bechuanaland, 61, 73.
Beira, 65, 70, 71.
Belat, 154.
Belgium, 253, 257.
Belgrade, 255, 259.
Bellenden Ker Hills, 347, 359.
Benares, 190, 194.
Bengal, 102, 103, 106, 109, 110, 111, 113, 117, 118, 126–7.
Bengal, Bay of, 101, 103, 107, 110, 111, 112, 118, 119, 121–3.
Benghazi, 23.
Benguela Current, 13, 46, 48, 60, 61, 70, 77.
Ben Nevis, 2, 213, 252, 257.
Benue R., 38.
Beowawe, 278.
Berber, 17, 40, 41.
Berbera, 44, 82, 86.
Beresov, 193, 196.
Bergen, 212, 213, 214, 216, 253, 258.
'Berg winds', 72.
Berlin, 221, 222, 223, 249, 254, 258.
Besançon, 258.
Bevers, 225, 226, 231, 255, 259.
Beyrut, 77, 154.
Biarritz, 252.
Birr, 252.
Biskra, 23, 81, 85.
Bismarck, 294, 295, 299, 301.
Bismarckburg, 33, 34, 81, 85.
Black Sea, 149, 150, 151, 172, 177, 179, 182, 183, 184, 189, 197, 202, 206, 242, 251.
Blackwood Range, 347.
Blagoveschensk, 182.
Blanc, Mont, 226.
Blantyre, 64.
'Blizzards', 276, 378–80, 384, 385.
Bloemfontein, 69, 73, 75.
Blue Mt., Jamaica, 336.
Bogota, 323, 324, 340, 342.
Boisé, 292, 293, 299, 301.
Bokhara, 186.
Bolivia, 319, 320.
Bolobo, 2, 47, 82, 86.
Boma, 47, 49.
Bombay, 70, 109, 112, 118, 190, 193.
Bonin Is., 142.
'Bora', 172, 239, 250.
Bordeaux, 252, 257.
Borku, 26.
Borneo, 145, 146.
Bornu, 38.
Bosphorus, 150, 151, 251.
Boston, 299, 301.
Bothnia, Gulf of, 181, 197, 219.
Bourbon, 67, 68.
Bourke, 350, 362, 369, 371.
Braemar, 252.
Braila, 260.
Bramaputra, 113, 163.
Brazil, 207, 303, 325–30.
Brazil Current, 306.
Brazzaville, 48.
Breslau, 222, 223, 258.
Brest, 210, 213, 214, 215, 216, 220, 221, 222, 257, 277, 284.
'Brick-fielders', 364.
Bridgetown, 341.
Brisbane, 352, 359, 360, 362, 369, 371.
British Columbia, 264, 267, 268, 271, 282, 286, 288.
British East Africa, 50–7, 83, 87.

British Isles, 200, 206, 252, 257.
British South Africa, 68–80, 84, 88.
Brittany, 212, 213.
Brocken, 254.
Broken Hill, 369, 371.
Broome, 370, 372.
Brünig Pass, 226.
Brussels, 216, 253, 257.
Buda-Pest, 220, 221, 222, 223, 255, 259.
Buenos Aires, 329, 332, 333, 334, 341, 343.
Bukarest, 220, 255, 260.
Bukoba, 55, 58.
Bulawayo, 69, 71, 74, 75, 76, 84, 88.
Bulgaria, 243.
'Buran', 174, 189, 276.
Burgos, 256.
Burma, 95–132.
Bushire, 191, 195.
Butiaba, 57.
Buxton, 252, 257.

'Cacimbo', 49, 60.
Cairns, 364.
Cairo, 23, 24, 25, 40, 41, 42, 82, 86.
Calcutta, 105, 113, 126, 190, 193.
Caldera, 315.
Calgary, 271, 299, 301.
Calicut, 105, 190, 193.
California, 267, 268, 274, 276, 277, 279, 280, 281, 282, 285.
California Current, 264, 279, 284.
'Calina', 244, 247.
Callao, 314, 315, 316, 340.
Cambay, Gulf of, 110, 115.
Cambridge, 215, 252.
Campinas, 343.
Canary Is., 21, 264.
Canaries Current, 11, 13, 20, 22, 28.
Cannes, 246.
Canterbury Plains, 367.
Canton, 134.
Cape Coast Castle, 33, 34, 36, 81, 85.
Cape Province, 16, 18, 61, 68, 72, 73, 76–80.
Cape Town, 11, 18, 62, 68, 69, 70, 74, 75, 77, 80, 84, 88.
Cape Verde Is., 30.
Caracas, 324, 340, 342.
Carlstad, 254.
Carnatic, 124–6.
Carnarvon, 370–2.
Cartagena, 342.
Cascade Range, 287, 288, 290.
Caspian Sea, 149, 153, 169, 171, 172, 176, 177, 181, 184, 197, 200, 202, 242.
Castile, 247.
Cattaro, 237.
Cauca R., 323.
Caucasus Mts., 151, 172, 189, 200.
Cawnpore, 190, 194.
Cayenne, 342.
Ceara, 328, 329, 343.
Celebes, 146.
Central America, 335–8.
Central Europe, 218–33.
Central Plateau of France, 213, 239.
Cevennes, 239.
Ceylon, 95–132.
Chad, L., 28, 33, 35, 39.
Chañaral Is., 315.
Chang, 162.
Charbin, 191.
Charleston, 268, 299, 301.
Charleville, 369, 371.
Cheng-tu, 134, 138, 191.
Cherbourg, 257.
Cherrapunji, 45, 113, 194.
Cheyenne, 272.
Chicago, 268, 272, 283, 299, 301.
Chichuahua, 344.
Chilca, 332.
Chili, 28, 240.
China, 95, 97, 132–9, 305, 329.
China Sea, 132, 133.
'Chinook winds', 271.
Christchurch (New Zealand), 365, 370.
Christiania, 212, 219, 254, 259.
Christiansund, 212, 219, 253, 258.
Chubut, 332, 335.
Chung-king, 135, 138, 194.
Chur, 231.
Cilicia, 151.
Cincinnati, 268.
Ciudad Real, 256.
Clanwilliam, 77.
Clermont-Ferrand, 216, 254, 258.
Cleveland, 300, 301.
Cloncurry, 369, 371.
Clyde, 366.
Coast Range, 271, 279, 286, 287, 288.
Cold Wall, 264.
'Cold waves', 275.
Colombia, 306, 307, 308, 312, 322.
Colombo, 112–190, 193.
Colon, 341, 344.
Colorado, 271, 274, 275, 278, 288.
Columbia R., 264.
Columbia, S.C., 283.
Columbus, 273.

Comoro Is., 67.
Concordia, 343.
Condon, 363.
Congo, 28, 30, 46–9, 60, 61, 82, 86.
Constantine, 81, 85.
Constantinople, 251, 256, 261.
Coolgardie, 370, 372.
Copenhagen, 254, 259.
Cordoba, 332, 333, 334, 341, 343.
Corfu, 243, 256, 261.
Corrientes, 332, 343.
Corsica, 243.
Cracow, 259, 260.
Crimea, 171, 172, 183, 184, 189, 246.
Crkvice, 237.
Culebra, 344.
Cunene R., 61.
Cuyaba, 326, 327, 328, 340.
Cyprus, 149, 152, 238.

Dacca, 113, 193.
Dakhla, 24, 26.
Dakota, 284.
Dalmatia, 236, 239.
Daly Waters, 370, 372.
Danube R., 219, 238.
Dar-es-Salaam, 83, 87.
Darjiling, 116, 190, 194.
Darling Downs, 360.
Darling Range, 347, 360.
Darling R., 347, 362.
Darwin, 350, 351, 352, 358, 359, 370, 372.
Davenport, 272.
Davos, 230, 231, 232, 255, 259.
Dawson City, 273, 282, 299, 301.
Death Valley, 278.
Debreczin, 208, 255, 259.
Debundja, 86.
Deccan, 98, 99, 101, 103, 112, 123.
Deerness, Orkney, 252.
Dega, 44.
Delhi, 113, 190, 194.
Denmark, 253.
Denver, 283, 300, 301.
Des Moines, 272.
Dinaric Alps, 239, 246.
Djole, 86.
Djurjura, 22.
Dniester R., 180.
Doleib Hill, 82, 86.
Donzère, 238.
Doorbaji (Sind), 115.
Drakensberg Mts., 19, 61, 69, 73, 79.
Duala, 82.
Dubbo, 359, 369, 371.
Dublin, 252, 257.
Dubuque, 272, 282.
Duluth, 272, 300, 301.
Dundee, 214.
Dunedin, 366, 370, 372.
Dungeness (Str. of Magellan), 252, 318.
Durban, 70, 71, 73, 74, 75, 78, 84, 88.
'Dust Devils', 153.

East Anglia, 214.
East Australian Current, 348, 366.
East Indies, 144–8.
East London, 71, 75.
Eastern Highlands of Australia, 347, 360, 365.
Eastport (Maine), 268.
Eberstein, 227.
Ebro R., 248.
Ecuador, 312, 319.
Edinburgh, 214, 216, 257.
Egmont, 367.
Egypt, 15, 23, 27, 39, 40–2, 149, 238.
Ekaterinoslav, 172.
Elbe R., 212, 220.
Elburz Mts., 153.
Elche, 200.
Eldama, 56, 83, 87.
El Golea, 25, 81.
El Obeid, 82, 86.
El Sheikh Fadl, 41.
Emden, 216, 258.
Engadine, 225, 232.
Enns R., 232.
Entebbe, 55, 83, 87.
Equatorville, 47, 48.
Equivalents, temperature °F and °C, 386; inches and millimetres, 387.
Erebus Mt., 377, 378.
Erfurt, 254.
Erie L., 273.
Eritraea, 43.
Erzerum, 151.
Estrella, S. da, 237.
'Etesian winds', 152, 234, 235.
Eucla, 370, 372.
Euphrates, 151.
Eureka, 277, 284, 300, 302.
Europe, Central, 197, 200, 201, 218–33.
Europe, N.W., 210–18.
Evangelist's Is., 317, 318, 340, 342.
Evans, C., 377–80, 382, 383, 385.
Eyre, L., 347, 360, 362.

Falkland Current, 306, 318.
False Bay, 77, 78.

Fanö, 253.
Farafra, 24.
Färoe Is., 210.
Ferghana, 169, 186.
Fiji Is., 364.
Finland, Gulf of, 181, 197.
Fiume, 222.
Flagstaff, 293, 294.
Florence, 236, 256, 261, 360.
Florida, 264, 267, 269, 274, 276.
'Föhn wind', 22, 62, 72, 149, 151, 229, 271, 367.
Formosa, 140, 142, 143, 191.
Fort Anderson, 64.
Fort Apache, 288.
Fort Chipewyan, 294, 295, 299, 301.
Fort Grant, 274, 278.
Fort Hall, 83, 87.
Fort Johnson, 83, 87.
Fort Laramie, 274.
Fort Portal, 56, 57.
Fort Smith, 50.
Fort William, 2, 252, 257.
Fortescue, 363.
Framheim, 374, 379, 380, 384.
France, 252, 254, 256, 257, 258, 261.
Frankfurt a. M., 258.
Franz Josef glacier, 366.
Fraser R., 271.
Freetown, 13, 34, 81, 85.
Fresno, 280.
Freudenstadt, 258.
'Friagem', 327.
Fruholmen, 253.
'Fruit Belt' (Michigan), 273.
Fuchou, 194.
Funchal, 81, 85.

Gabun R., 46.
Galveston, 267, 268, 276, 283, 294, 295, 300, 302, 338.
Ganges R., 97, 99, 115.
Ganjam, 119.
Garbi, 240.
Garonne R., 213.
'Garua', 313.
Gata, C. de, 240.
Gauhati, 113.
'Gauss', 376, 381.
Gazaland, 65.
Geneva, 232, 238, 255, 259.
Genoa, 238, 244, 256, 261.
Genoa, Gulf of, 238, 239, 242, 246.
Georgetown, 324, 340, 342.
Georgia, 171, 189, 243.
Georgia, Str. of, 207.
Geraldton, 359, 370, 372.
Germany, 253, 254, 257, 258.
Géryville, 22, 23, 81, 85.
Ghats, Western, 110, 112, 115.
Ghir, C., 20.
Ghouph, 79.
Gibli, 240.
Gibraltar, 21, 256, 260.
Gila, 278.
Gila Bend, 293, 294.
Glenora, 286.
Goalpara, 120.
Gobi, 89, 155, 159.
Godavari, 120.
Golden Gate, 279, 280.
Gondar, 43.
Gondokoro, 83, 87.
Gopalpur, 194.
Gorée, 81, 85.
Göteborg, 254.
Graaf Reinet, 69, 78, 79, 84, 88.
Grahamland, 374.
Grand Banks, 264.
Grand Bassam, 36.
Grand Haven, 272.
'Grape Belt' (New York), 273.
Graz, 227, 255.
Great Bear Lake, 273.
Great Lakes of N. America, 262, 267, 272, 282, 290, 291, 294, 296, 298.
Great Valley of California, 279, 280, 281, 287.
Great Valley of Victoria, 360.
Greece, 238.
Greenwich, 213.
Grenoble, 258.
Groningen, 253.
Grootfontein, 62, 87.
Guardafui, C., 13, 18.
Guatemala, 341, 344.
Guayaquil, Gulf of, 313.
Guiana, 304, 307, 322, 324.
Guinea, 15, 16, 17, 24, 28–39, 45, 49.
Guinea Current, 13, 34, 46.
Gulf Stream, 197, 207, 264, 265.

Hakiao, 156.
Hakodate, 195.
Halifax, 272, 296, 297, 299, 301.
Hamburg, 212, 216, 220, 253, 258.
Hanover, 79, 80, 254, 258.
Hankow, 134, 135, 191, 194.
Haparanda, 219, 254.
'Harmattan', 35, 39.
Harrisburg, 300, 302.
Harvey Creek, 359, 371.

Hasli Thal, 226.
Havana, 341, 344.
Hebron, 210, 299.
Helder, 257.
Helena, 300, 302.
Helvetia (Melsetter), 88.
Hermanstadt, 260.
Hernosand, 254, 259.
Himalayas, 97, 98, 99, 110, 115, 116, 131, 166.
Hoang-ho, 134.
Hobart, 352, 362, 369, 371.
Hokitika, 365, 368, 372.
Holland, 253, 257.
Holyhead, 252.
Hondo, 139, 140, 141, 142, 143.
Hong Kong, 134, 135, 136, 142, 191, 194.
Horn of Africa, 44–5.
Hoshangabad, 190.
Hudson Bay, 262, 266, 273, 282.
Hué, 191, 194.
Humboldt Current, 306, 315.
Humboldt R., 278.
Hungary, 218, 251, 255, 259.
'Hurricanes', W. Indies, 338–9.
Hut Pt., 381, 382.
Hüttenberg, 227.
Hyderabad, 115, 123.

Iberian Peninsula, 203, 236, 238, 246, 248.
Ice Barrier, 374, 375, 378, 383, 384.
Iceland, 201, 203, 206.
Ichang, 136, 194.
Idaho, 274, 288.
India, Ceylon, and Burma, 95–132.
Indianapolis, 300, 302.
Indus R., 112, 115, 163.
Inland Sea, 142.
Inn R., 232.
Innsbruck, 255, 259.
In-salah, 26, 27, 81.
'inversion of rainfall', 161.
'inversion of temperature', 226–8, 274.
Iquique, 315, 316, 317, 340, 342.
Iquitos, 325, 326, 343.
Irgis, 179, 193, 196.
Irkutsk, 193, 196.
Ischl, 259.
Ishinomaki, 195.
Ispahan, 195.
Italian lakes, 246.
Italy, 256, 260, 366.

Jacobabad, 103, 113, 115, 116, 190, 194.
Jaffa, 152, 154.
Jaipur, 190, 194.
Japan, 95, 139–43.
Japan Sea, 139–40.
Java, 144, 146.
Jerusalem, 154, 195.
Johannesburg, 74, 76.
Juan Fernandez, 315.
Juba, 51.

Kabul, 191, 195.
Kafue, 64.
Kagoshima, 139, 191, 195.
Kalahari, 11, 61, 63.
Kalomo, 87.
Kamerun, 34, 45–6, 82, 86.
Kamerun Peak, 34.
Kamloops, 271, 282, 284, 299, 301.
Kampala, 57.
Kanazawa, 195.
Kandy, 112.
Kanizsa, 222.
Kano, 38, 85.
Kapti, 51, 53.
'Karaburan', 159.
Karachi, 112, 114, 190, 194.
Kara Kum, 182.
Karembe, C., 150.
Karesuando, 219.
Karlsruhe, 220, 221, 254.
Karlstad, 219, 222.
Karroo, Great, 69, 72, 78.
Karroo, Little, 69, 75, 78.
Kars, 171, 192, 196.
Karst plateau, 239.
Kasan, 177, 192, 196.
Kashgar, 156, 157, 158, 159, 179, 192, 195.
Kashmir, 130–1.
Kassala, 82, 86.
Katanga, 49.
'Kaus', 152.
Kayes, 81, 85.
Kenya Colony, 50–7, 58, 83, 87.
Kenya, Mt., 50, 53, 56, 57.
Kew, 212, 252.
Key West, 268, 276, 283.
'Khamsin', 28, 40, 154, 240.
Khartoum, 5, 40, 41, 42, 82, 86.
Khasi Hills, 112, 113.
Khroumirie, 22.
Kiandra, 352, 369, 371.
Kiangsi, 134.
Kief, 192, 196.
Kiel, 222, 254, 258.
Kikuyu, 50, 53, 54, 55.

Kilimanjaro, 53, 57.
Killarney, 213.
Kimberley, 71, 73, 74, 84, 88.
Kingston, 284, 336, 337, 341, 344.
Kioga, L., 56.
Kiriake, 141.
Kisil Kum, 182.
Kismayu, 51, 87.
Kisumu, 56, 83.
Kiu, 53.
Kiu-shiu, 140, 141, 142, 143.
Kiusu, 165.
Klagenfurt, 220, 227, 228, 255, 259.
Knoxville, 297, 298.
Knysna, 88.
Kochi, 195.
Kola, 171, 176, 192, 196.
Kolla, 43.
Köln, 219, 258.
Komati Poort, 70, 84.
Konakry, 34.
Königsberg, 254, 258.
Kootenay, B.C., 290.
Korea, 138, 142.
Kosciusko Mt., 347, 352.
Koury, 35.
Krasnovodsk, 196.
Krasnoyarsk, 185.
Kufra, 25.
Kuka, 81.
Kuku Nor, 165.
Kurdistan, 152.
Kuro Siwo, 139, 143, 146, 264.
Kursk, 192, 196.

Labrador, 210, 264, 272, 277, 282, 294.
Labrador Current, 264, 282, 284.
Lagos, 81, 85, 287.
La Guayra, 324, 326, 340.
Lahore, 100, 101, 190, 194.
Lake District, England, 213.
La Paz, 320, 321, 340, 342.
Lärdal, 253.
La Rioja, 343.
Larissa, 237.
La Serena, 315, 342.
Las Palmas, 81, 85.
Lauderdale, 64, 83, 87.
Lealui, 87.
Lebanon, 154.
Leghorn, 236.
Leh, 116, 131–2, 190, 194.
Leikipia, 51, 53.
Leipzig, 254, 258.
Leith, 252.
Lemberg, 255.
Levant, 149, 240.
‘Levèche’, 240.
Lexington, 272.
Lhassa, 164, 165.
Libau, 181.
Liberia, 33.
Libreville, 46, 86.
Libyan desert, 23, 26, 27, 28.
Lille, 252, 257.
Lima, 313, 340, 342.
Limpopo R., 69, 76.
Lisbon, 50, 51, 245, 247, 256, 260, 317.
Livingstone, 83.
Livingstone Range, 58.
Loanda, 49, 60.
Lofoten Is., 219, 249.
Lokoja, 38, 85.
Lolling, 227.
London, 2, 211, 212, 213, 214, 216, 252, 257.
Longonot, Mt., 54.
Lopez, C., 13.
Los Angelos, 268, 274, 279.
Lourenço Marques, 65, 71.
Luangwa, 64.
Lübeck, 220.
Lucerne, 225, 226, 228, 230, 231, 255, 259.
Lu-chu Is., 142.
Lüderitz Bay, 62.
Lugano, 229, 231, 232, 256.
Lukchun, 156, 157, 159, 168, 179, 192.
Luluaburg, 48, 60, 82, 86.
Lyon, 216, 254, 258.

MacDonnell Range, 347.
Machakos, 83.
Mackenzie R., 273, 282.
Madagascar, 66–8, 84, 88.
Madeira R., 326.
Madras, 112, 119, 120, 123, **124–6**, 190, 193.
Madrid, 247, 248, 256, 260.
Magdalena R., 323.
Magellan, Str. of, 318.
Maine, 283.
Makindu, 87.
Makran, 153.
Malacca Strs., 144.
Malay Peninsula, 95, 145.
Malta, 242, 245.
Manaos, 325, 326, 327, 340, 343.
Manchuria, 142.

Mandalay, 190, 193.
Mangalore, 112.
'Mango-showers', 105, 125.
Mannheim, 219.
Mareb R., 43.
Mariehamn, 171, 176, 192.
Maritsa, 243.
Markham, Mt., 374.
Marmora, S. of, 238.
Marseilles, 150, 242, 243, 246, 256, 260.
Martinique, 344.
Massaua, 44, 86.
Matjesfontein, 88.
Mau Escarpment, 51, 54.
Maud Ranges, 374.
Maungu, 52.
Mauritius, 67, 68.
Mazanderan, 153.
Mazatlan, 341.
Mbale, 57.
Mbarara, 57.
McMurdo Sd., 377, 381, 382, 383, 384, 385.
Medicine Hat, 271, 282, 284.
Mediterranean Africa, 19–24, 81, 85.
Mediterranean Lands, 19–24, 200, 208, 222, 233–51.
Mediterranean Sea, 13–15, 17, 19, 24, 40, 41, 98, 148, 149, 150, 154, 197, 202, 204, 236, 237, 240, 241, 242.
Meiringen, 226.
Mekong R., 163.
Melbourne, 350, 351, 352, 362, 364, 369, 371.
'Meltem,' 234.
Memel, 219, 220.
Mendocino C., 287.
Mendoza, 333.
Meroe, 41, 42.
Merv, 172, 196.
Meseta, Spanish, 243, 247.
Mesopotamia, 97, 148–54.
Metz, 258.
Mexico, 335–9.
Mexico City, 337, 341, 344.
Mexico, Gulf of, 262, 265, 266, 267, 268, 269, 274, 275.
Mfumbiro, 55.
Miami, 300, 302.
Michigan, L., 272.
Milan, 249, 256, 261.
Miles City, 274.
Milwaukee, 272, 282.
Minnedosa, 271.
Misahöhe, 81, 86.
Mississippi R., 262, 267, 269, 275, 276, 278, 283, 285.
Missouri R., 267, 285.
Misti, Mt., 340.
'Mistral', 238, 239.
Mlanje, 64.
Mobaye, 48, 86.
Mogador, 11, 20, 22, 81, 85, 277, 284.
Mohave, 278.
Mohawk Summit, 278.
Mollendo, 314, 315.
Molopo R., 63.
Mombasa, 51, 53, 56, 65, 83, 87.
Mongalla, 5, 40, 41, 42, 56, 82, 86.
Mongolia, 155, 156, 161.
Monkira, 362.
Montana, 274.
Montaña, 327.
Monte Video, 329, 343.
Montgomery, 300, 302.
Montpellier, 242, 256, 260.
Montreal, 282, 291, 296, 297, 299.
Mooltan, 105, 113, 190, 194.
Mopeia, 65, 70, 84, 88.
Moraine, L., 274.
Morocco, 15, 19, 20, 21, 22, 28, 81, 85.
Moscow, 176, 177, 178, 192, 196.
Mosul, 152, 153, 190, 195.
Mozambique, 13, 16, 65, 67, 68, 84, 88.
Mozambique Current, 70, 77.
Muanza, 59, 83, 87.
Mukden, 194.
Munich, 220, 221, 254, 258.
Münster, 258.
Murcia, 256, 260.
Murman Coast, 171, 181.
Murray R., 347.
Murree, 116.
Murzuk, 24.
Musgrave Range, 347.
Mussooree, 116.

Nain, 277, 284, 299.
Naini Tal, 116.
Nairn, 213, 252, 257.
Nairobi, 53, 56, 83, 87.
Naivasha, 54, 87.
Nakuru, 54.
Nandi, 55.
Nantes, 208, 252.
Napier, 366, 370.
Naples, 241, 242, 245, 246, 256, 261.
Nashville, 300, 302.
Natal, 18, 68, 72, 73, 76.
Negro R., 326.
Neuquen, 335.

Nevada, 274, 278.
Nevada de S. Marta, Sierra, 322.
Nevada, Sierra, California, 277, 280, 288, 290.
Nevada, Sierra, Spain, 246, 249.
New Antwerp, 48, 82, 86.
Newcastle, 257.
Newfoundland, 264.
New Guinea, 145.
New Mexico, 277.
New Orleans, 268, 276, 283, 300, 302.
New Plymouth, 370.
New Siberian Is., 182.
New Westminster, 271.
New York, 268, 277, 283, 284, 296, 297, 300, 302.
New Zealand, 365–8.
Ngami, L., 63.
Nice, 210, 241, 245, 246, 256, 260.
Niger R., 31, 34, 38, 39.
Nigeria, 37–9, 45, 81, 85.
Nikolaievsk, 182, 188.
Nile R., 17, 27, 39–42, 43, 56.
Nimule, 57.
Njoro, 55.
Nkata Bay, 83, 87.
No, L., 42.
N. America: Pressure and winds, 265–9; Temperature, 269–86; Rainfall, 286–98.
North Atlantic Drift, 207, 213.
'Northers', 276, 282.
North-Pacific Drift, 264.
North-west Europe, 210–18.
North-west Frontier (India), 99, 101, 103.
North-west Province, 109.
Norway, 206, 208, 253, 258.
'Nor-Westers' (India), 106.
Noto, 143.
Nottingham, 257.
Nova Zemlya, 182.
Novorossiisk, 172.
Nukuss, 172.
Nullagine, 370, 372.
Nurnberg, 258.
Nyasa, L., 58, 63, 64.
Nyasaland, 63–5, 83, 87.
Nyika, 52.

Obidos, 326, 327.
Obir, 228.
Oder R., 219.
Odessa, 192, 196.
Ohio, 266.
Okayama, 195.
Okhotsk, 179, 183, 193, 196.
Okhotsk Current, 139.
Olympia, 292, 293, 300, 302.
Omaha, 272, 283, 294, 295, 300, 302.
Oman, 154.
Ona, 253.
Onega Bay, 182.
Onslow, 370, 372.
Ontario, 272.
Ontario, L., 273.
Oporto, 277, 284.
Orange R., 61.
Orange River Colony, 72, 73.
Oregon, 267, 268, 274, 286, 287, 288.
Orenburg, 192, 196.
Orissa, 119.
Orkney Is., 210, 252.
Osaka, 191.
Oslo (*see* Christiania).
Ostend, 257.
Ostersund, 259.
Oswego, 300, 302.
Otago, 366.
Ottawa, 272, 299, 301.
Oudtshoorn, 78, 88.
Ouro Preto, 343.
Oxford, 174, 214, 216, 252, 257.

Pachmarhi, 190.
Padua, 261.
Palermo, 240, 246, 256, 261.
Palestine, 148, 149, 152, 238.
Palmietfontein, 72.
Pamirs, 161–2.
Pamirski Post, 162.
'Pampero', 334.
Panama Canal Zone, 2, 337–8, 344.
Pangani, 59.
'Papagayos', 336.
Para, 325, 326, 340, 343.
Paraguay, 327–30.
Paramos, 324.
Paris, 211, 212, 213, 216, 220, 221, 252, 257.
Parry Sound, 296, 297.
Patagonia, 309, 318, 335.
Patna, 113, 190, 194.
Peking, 1, 2, 5, 134–37, 191, 194.
Pella, 73.
Penang, 145, 191, 195.
Pernambuco, 326, 329, 340, 343.
Persia, 98, 148–54.
Persian Gulf, 149, 152, 153.
Perth (West Australia), 348, 352, 361, 362, 370, 372.
Peru, 319.

Peshawar, 99, 101, 120, 190, 194.
Petro-Alexandrovsk, 179, 192, 196.
Petrograd, 171, 176, 185, 192, 196.
Philippine Is., 145, 146–8.
Piacenza, 249.
Piauhy, 329.
Pic du Midi, 232.
Pietermaritzburg, 73, 84, 88.
Pike's Peak, 268, 274, 290, 300, 302.
Pilbarra, 348, 349, 351, 356.
Pinal Ranch, 288.
Pine Bluff, 300, 302.
Pittsburg, 295, 296, 300, 302.
'Plum rains', 137, 142–3.
Plymouth, 257.
Po R., 243, 246, 249.
Po-jang, L., 134.
Poona, 190, 193.
Poplar R., 274.
Port Antonio, Jamaica, 336, 344.
Port Arthur, 299, 301.
Port Elizabeth, 71, 75, 78, 84, 88.
Port Florence, 55, 87.
Port Galera, 317.
Portland (Ore.), 241, 268, 300, 302.
Port Macquarie, 369, 371.
Port Nolloth, 70, 72, 73, 76, 77, 84, 88.
Porto Alegre, 329.
Portree, 271, 277, 284.
Port Said, 23, 40, 81, 85.
Port St. John's, 84.
Port Simpson, 292, 293, 299.
Port Sudan, 82, 86.
Port Tortuga, 315.
Portugal, 256, 261.
Portuguese East Africa, 65, 84, 88.
Posen, 254, 260.
Prague, 222, 223.
Pretoria, 69, 70, 72, 75, 84, 88.
Provence, 239.
Puget Sound, 287.
Punjaub, 98, 99, 100, 109, 114, 115, 116, 118, 123, 127–9.
Punta Arenas, 318, 343.
'Purga', 174.
Puy de Dôme, 254.
Pyrenees, 200, 213.

Qu'appelle, 271, 301.
Quebec, 263, 299, 301.
Quetta, 191, 195.
Quito, 319–20, 340, 342.

Ragusa, 256, 261.
Raipur, 194.
Rajputana, 101, 115, 123.
Raleigh, 294, 295, 300, 302.
Ramah, 301.
Rangoon, 190, 193.
Red Bluff, 279, 280.
Red Sea, 13, 14, 15, 28, 44, 154.
'Redwood tree', California, 279.
Reichenau, 231.
Reno, 268.
Reuss, R., 228, 229.
Rhine, R., 219, 229, 231, 232.
Rhodesia, 49, 63–5, 71, 72, 73, 74, 75, 83, 87.
Rhone, R., 232, 238, 239, 245.
Rift Valley Eastern (E. Africa), 51, 53, 54, 57.
Rift Valley, Western (E. Africa), 55, 56.
Riga, 177, 178, 181, 192, 196, 260.
Rigi, 225, 226, 227, 230.
Rio de Janeiro, 340, 343.
Rio Grande do Sul, 343.
Ripon Falls, 56.
Riverina, 360.
Riviera, 241, 244, 246, 249, 250.
Roaring Forties, 310, 312, 355, 375.
Rocky Mts., 262, 271, 288, 290.
Rome, 210, 218, 242, 245, 246, 256, 261.
Röros, 253, 254, 259.
Rosario, 333, 341, 343.
Ross Sea, 373, 374, 375, 379, 384.
Ruapehu, 367.
Rudolf, L., 54.
Russian Empire, 97, 167–89, 192, 196.
Ruwenzori, 56.

Sacramento R., 279, 288, 300, 302.
Sagastyr, 170.
Sahara, 11, 14, 15, 16, 17, 19, 22, 23, 24–8, 29, 30, 33, 36, 43, 61, 154, 156, 158.
St. Gall, 228.
St. Gothard, 227, 232, 255.
St. John's, 277, 284, 296, 297, 299, 301.
St. Lawrence, Gulf of, 282, 291, 298.
St. Louis, 269, 275, 278, 283, 295, 296, 300, 302.
St. Malo, 241.
St. Paul, 268, 300, 302.
St. Roque, C., 207, 306.
Sakhalin, 140.
Sale, 369, 371.
Salem, 300, 302.
Salisbury, 69, 70, 71, 74, 84, 88.
Salonika, 206, 246, 250, 256, 261.

Salta, 333.
Salt Lake City, 292, 293, 300, 302.
Salwen, 163.
Salzach, 232.
Salzburg, 220, 221.
Samara, 185.
Samarkand, 192.
Samburu, 52.
San Antonio, 276, 283, 300, 302.
Sandakan, 145, 191, 195.
San Diego, 277, 284, 287, 292, 293, 300, 302.
San Francisco, 268, 279, 280, 281, 287, 292, 293, 300, 302.
San Joaquin, 279, 288.
San Juan, 332, 333, 334, 341, 343.
San Luis, 343.
Sanpo, 113, 163.
San Remo, 241.
'Santa Ana', 281.
Santa Anna do Sobradinho, 343.
Santa Cruz, 341, 343.
Santa Fé, 343.
Säntis, 226, 230, 231, 232, 255, 259.
Santos, 329, 343.
São Francisco, R., 328.
Saône, R., 219.
São Paulo, 327, 330, 340, 343.
Sapporo, 139, 191.
Saratov, 192, 196.
Sardinia, 243.
Sargans, 232, 255, 259.
Santiago (Argentine), 332, 333, 341, 343.
Santiago (Chile), 317, 333, 340, 342.
Santiago (Spain), 256, 260.
Saskatchewan, 290, 291.
Sault Ste. Marie, 272.
Scandinavia, 197, 203, 218, 254, 259.
Scilly Is., 1, 2, 212, 252.
Seathwaite, 257.
Semipalatinsk, 193, 196.
Senegal, 17, 28, 30, 33.
Serra da Estrella, 237.
Serra do Mar, 329, 330.
Seville, 248, 256, 260.
Seychelles, 67.
'Shamal', 152.
Shanghai, 134, 135, 136, 137, 139, 191, 194, 277, 284.
'Sharki', 152.
Sheikh, 45.
Sherman, 286.
Shetland Is., 206.
Shigatse, 165.
Shikoku, 140, 141, 142, 143.
Shillong, 113, 194.
Shirati, 55, 58.
Shiré, 63, 64.
Shotts, 19, 22–3.
Shreveport, 283.
Shrewsbury, 257.
Siam, 145.
Sicily, 240, 242, 243, 249.
Siebenbürgen, 222.
Sierra Leone, 16, 31, 33, 34, 45.
Sierra Nevada: California, 277, 280, 288; Spain, 246, 249; de S. Marta, 322.
Simferopol, 196.
Simla, 116, 129–30, 190, 194.
'Simoon', 28.
Sind, 17, 95, 103, 110, 114, 115, 117, 123.
Singapore, 144, 145, 191, 195.
Sinope, 151.
Sion, 259.
'Sirocco', 22, 28, 149, 154, 240.
Sitka, 271, 277, 284, 292, 299, 301.
Siva, 24.
Sivas, 151, 195.
Skomvaer, 219, 249, 253.
Skudesnaes, 219, 253.
'Smokes', 49.
Smyrna, 152, 195.
Snow covering, effects of, 185.
Snowdon, 213.
Snow Hill, 376, 381.
Sofia, 255, 260.
Sogne Fiord, 213.
Somaliland, 13, 44–5, 51, 82, 86.
South America, north of the Equator, 322–4.
South America, West Coast, 312–18.
'Southerly Burster', 334, 364.
South-east Asia, 144–8.
South Orkneys, 376, 378, 381.
South-west Africa, 11, 13, 19, 46, 60, 61–3, 70, 76, 83, 87.
South-west Asia, 148–54.
Spain, 256, 261.
Springfield, 278.
Srinagar, 99, 101, 130, 190, 194.
Stanovoi Mts., 174.
Statistics:
  Africa, 81–8.
  America, North, excluding Mexico, 299–302.
  America, South and Central, Mexico, and the West Indies, 340–4.
  Asia, with European Russia, 190–6.
  Australia and New Zealand, 369–72.
  Europe, excluding Russia, 252–61.

Stelzing, 227.
Stettin, 254, 258.
Stirling Range, 347.
Stockholm, 219, 254.
Stockton, 280.
Styehead Pass, 213.
'Suahili', 152.
Suakin, 17, 28.
Sucre, 342.
Sudan, 11, 15, 27, 28–42, 43, 47, 81, 82, 85, 86.
Sulina, 220, 255.
Sumatra, 144, 146.
'Sumatras', 144.
Sunda Is., 144, 145, 146.
Superior, L., 272.
Suwa, 142.
Swakopmund, 83, 87.
Swan Valley, 274.
Sweden, 223.
Swinemünde, 220.
Swiss Foreland, 224, 225, 226, 228.
Switzerland, 255, 259.
Sydney, 348, 359, 362, 369, 371.
Sylhet, 113.
Syr-Daria, 186.
Syria, 99, 148–54, 238.
Szegedin, 220, 259.
Szetchuan, 134, 137, 138, 143.

Table Bay, 77, 78.
'Tablecloth', 77.
Table Mountain, 77.
Tabora, 58, 59, 83, 87.
Taihoku, 191.
Taimyr P., 182.
Takla Makan, 155, 157, 158, 160.
Tamalpais, Mt., 280, 281.
Tamatave, 84, 88.
Tanganyika, L., 51, 58, 65.
Tanganyika Territory, 52, 57–9, 83, 87.
Tangier, 77.
Tarim Jangiköl, 158, 159.
Taru Jungle, 52, 53.
Tashkent, 176, 179, 186, 192, 196.
Tasmania, 361.
Taurus, 151.
Teheran, 191, 195.
Tehuantepec, 335, 337.
Tell, 22.
'Temporales', 336.
Tengri Nor, 165.
Tennasserim, 112.
Texas, 267, 268, 276, 282, 284.
Thar desert, 103, 114–15.
Thian Shan, 161.
Thorshavn, 210, 211, 214, 216.
Three Points, C., 34.
Tibesti, 27.
Tibet, 97, 162–6.
Tierra caliente, fria, templada, 324, 337.
Tierra del Fuego, 305.
Tiflis, 192, 196.
Tigris R., 153.
Tilsit, 219.
Timbuktu, 32, 33, 35–7, 42, 81, 85.
Timor, 144, 145.
Timor Sea, 363.
Titicaca, L., 321.
Tobolsk, 174, 177, 178, 193, 196.
Tokio, 141, 191, 195.
Toledo, 273.
Tomsk, 176, 177, 193, 196.
'Tornadoes', 37, 38, 49, 285.
Toro, 26.
Toronto, 296, 297, 299, 301.
'Tramontane', 240.
Transvaal, 73.
Trebizond, 150.
Trieste, 239, 246, 256, 261.
Trincomalee, 112, 190, 193.
Tripoli, 23, 81, 85, 242.
Trogen, 228, 229.
Tromsö, 253.
Trondhjem, 253, 258.
Tropical cyclones: Arabian Sea, 110; Bay of Bengal, 107, 110; North-west Australia, 363–4; China Seas, 146–8; South Indian Ocean, 67; South Pacific Ocean, 364; West Indies, 338–9.
Tsaidam, 165.
Tucson, 278.
Tumbez, 313.
Tunis, 19, 22, 23, 81, 85.
Turan, 89, 168, 169, 171, 172, 176, 179, 184, 186, 189.
Turfan, 156, 157.
Turin, 243.
Turukhansk, 185.
Tuscany, 250.
Tuticorin, 193.
'Typhoons', 146–8.
Tyrrhenian Sea, 240.

Ubangui, 48.
Uganda, 50–7, 83, 87.
Ujiji, 58, 87.
Uliassutai, 157, 159.
United Provinces, 103, 118, 123.

Unyamwezi, 58.
Uppington, 73.
Ural Mts., 167.
Urga, 156, 157, 159, 192.
Uruguay, 327–30.
Ushuaia, 341, 343.
Uskub, 255, 259.
Uspallata, 341, 343.
Usumbara Heights, 58.
Utah, 274.
Utrecht, 253, 257.

Valdivia, 317, 340, 342.
Valencia, 211, 212, 213, 214, 215, 216, 218, 245, 246, 252, 257.
Valladolid, 260.
Valparaiso, 315, 316, 317, 342.
Vancouver Is., 271, 282, 286.
Vardö, 253.
Veld, 69, 72, 79.
Venezuela, 303, 307, 322.
Venice, 238, 249.
Vera Cruz, 337, 341, 344.
Verde, C., 34.
Verkhoyansk, 170, 173, 176, 177, 179, 193, 196.
Vicksburg, 283, 297, 298, 300, 302.
Victoria (Vancouver Is.), 271, 277, 284, 299, 301.
Victoria Falls, 65, 69, 88.
Victoria, L., 54, 55, 56, 57, 58, 59.
Vienna, 208, 255, 259.
Vistula R., 167, 180.
Vivi, 47.
Vladivostok, 139, 171, 182, 183, 193, 196, 277, 284, 297, 298.
Voina Dega, 43.
Volga R., 180, 185.
Volo, 237.
Vryburg, 74.

Wadelai, 41, 42, 56, 83, 87.
Wadi Halfa, 41, 82, 158.
Wagaduga, 81, 85.
Wahsatch Range, 288.
Walfish Bay, 61, 62, 75.
Warsaw, 192, 196, 260.
Warshekh, C., 13.
Washington, 268, 274, 287, 288, 300, 302.
Weddell Sea, 373, 374.
Welle R., 48.
Wellington, 370, 372.
Wener, L., 219.
West Indies, 335–9; Hurricanes of, 338–9.
White Sea, 171, 181, 197.
Wilcannia, 369, 371.
Willamette Valley, 287.
William Creek, 370, 372.
‘Williwaws’, 318.
‘Willy-willies’, 363.
Windhoek, 62, 83, 87.
Windward Is., 336.
Winnipeg, 271, 272, 282, 294, 295, 299, 301.
Wyndham, 370, 372.

Yaila Mts., 172, 184, 246.
Yakutsk, 176, 177, 178, 193, 196, 210.
Yalta, 172, 186, 192, 196.
Yangtse, 134, 135, 137, 138, 142, 163.
Yarkand, 156, 157, 159.
Yaundé, 5, 82, 86.
Yellowstone Valley, 274.
Yemen, 154.
Yezo, 140, 141, 142, 143.
York, 252.
York, C., 369, 371.
Yukon R., 273, 282.
Yuma, 274, 288, 300, 302.
Yunnan, 138.

Zambesi, 63, 64, 65, 69, 73, 76.
Zante, 236, 245.
Zomba, 64, 65, 83, 87.
‘Zonda’, 335.
Zumbo, 64, 65.
Zürich, 231.

PRINTED IN GREAT BRITAIN AT THE UNIVERSITY PRESS, OXFORD
BY JOHN JOHNSON, PRINTER TO THE UNIVERSITY